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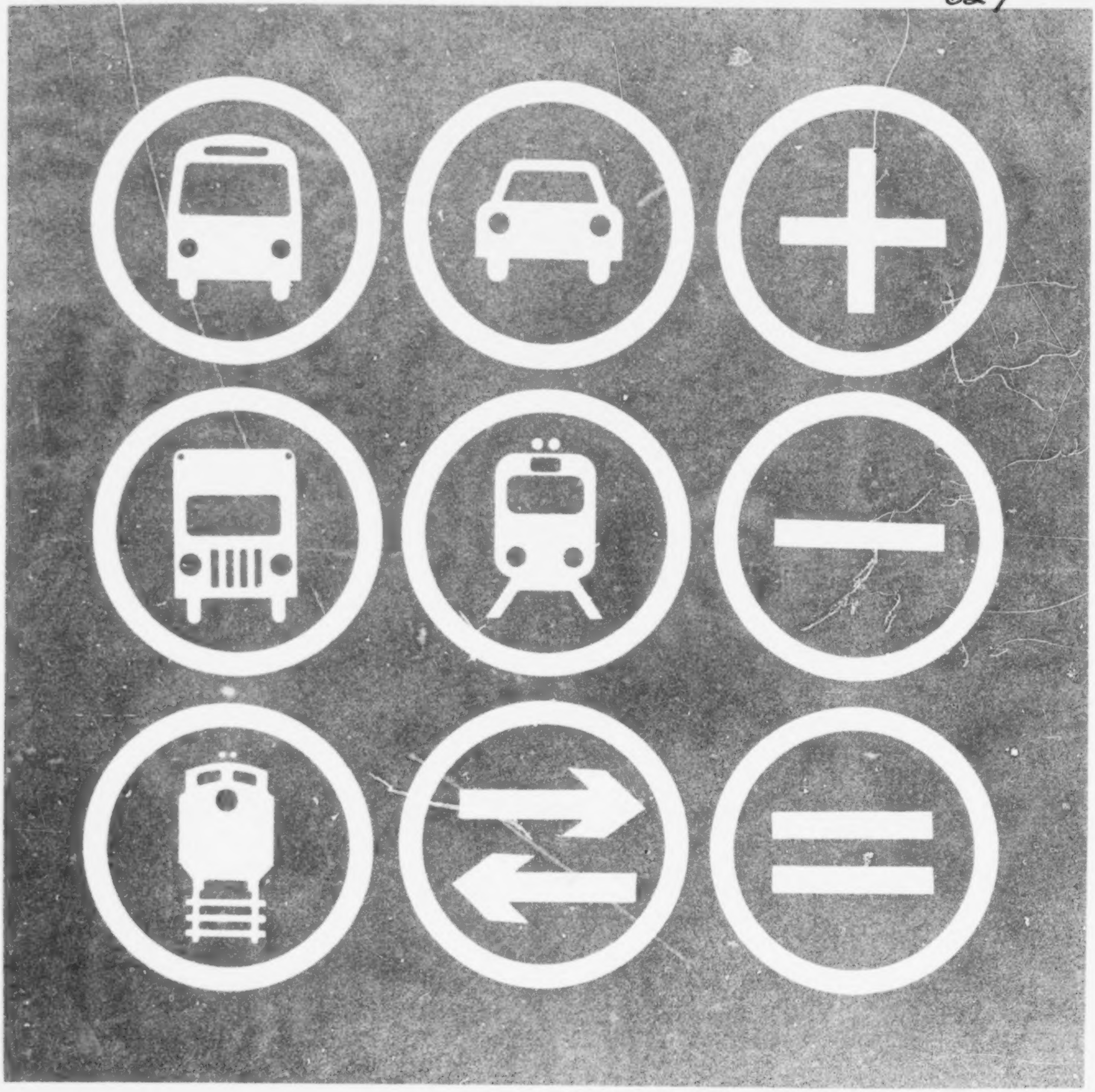

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Proceedings
# of the
International Symposium on Surface Transportation System Performance

Volume II

Sponsored by:

U.S. Department of Transportation
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Federal Highway Administration

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PREFACE

The International Symposium on Surface Transportation System Performance was a three-day meeting consisting of general and focused discussions of the state-of-the-art, policy issues, and concepts and definitions used in the evaluation of the performance of transportation systems. The overall motivation for the Symposium was to provide a forum in which transportation officials, policymakers and technical experts could explore the techniques and programs used by other countries to assess the efficiency and effectiveness of their transit systems. Specifically, five topics were chosen which focused the workshop session discussions on those areas which were and are of prime importance in the complex area of evaluating performance: energy conservation, economic development, urban form, impact of the transportation system on the environment, and safety.

The organization of these Proceedings follows generally the organization of the Symposium. The keynote speeches presented at the plenary sessions are provided in Volume I, together with summaries of the content of each of the fifteen workshop sessions, and a list of the Symposium participants. In Volume II, the complete texts of the fifty technical papers presented at the workshop sessions are recorded.

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EVALUATION OF ENERGY AND TRANSPORTATION PERFORMANCE

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Abstract

This paper assesses the current state of the art in evaluating the interrelationships of national energy and transportation programs. The author discusses briefly the limitations of using single modal indicators of transportation performance and energy conservation, and suggests five factors which influence our ability to assess future energy impacts of alternative transportation policies on a national sector basis. The author then recommends development of a package of indicators for use in such assessments through an international research program specifically designed for that purpose and suggests ten issues as a point of departure for that effort.

Introduction

The purpose of this paper is twofold:

1. to assess the current state of the art in evaluating the interrelationships of national energy and transportation programs and impacts, and

2. to identify guiding principles for conducting effective analyses of energy consumption impacts of alternative transportation policies. The paper is intended to apply a broad-brush approach to these issues and to help establish direction for research into more definitive ways of assessing transportation and energy relationships. The paper addresses the issues from the perspective of the national transportation sector and its relative consumption of energy.

Energy and Transportation Linkages--The Measurement Problem

Recently a research group of the organization for Economic Cooperation and Development (OECD), which I chaired, found that while we were able to produce and publish a report on evaluation of public transportation performance ("Urban Public Transport: Evaluation of Performance"; OECD, Paris, 1980), the effort seemed too narrow to serve real transportation decisions on a broad scale. OECD countries now face new and different issues of transportation efficiency and effectiveness, and performance evaluation approaches are largely absent.

General agreement now exists among nations on the urgency of the energy issue, but the problems involved are complex and confront many Western countries with challenges in collective action, especially in transportation. As indicated recently by the Economic Commission for Europe (ECE), "the common theme emerging from ... governments is the need to reduce specific energy consumption relative to economic growth, while meeting energy requirements at the same time."[1] The ECE goes on to say:

> Although progress has been satisfactory since 1973, there are disturbing indications that this progress may not be maintained in all ECE countries: the rate of growth of energy demand for the period 1978-1990 is expected to accelerate in comparison with the period 1973-1978; energy economy and efficiency will improve only at sharply reduced rates; the rate of growth of production from indigenous sources will decline; new and renewable sources will not make a substantial contribution to energy supplies; imports of coal and gas will increase significantly for most countries; oil import demand will remain at high relative and absolute levels which the world oil market would be unlikely to supply.[2]

With regard to the interrelationships of energy and the transportation sector, a statement issued by the United Kingdom, again in an ECE report, is illustrative of the issue of formulating public policy in a free market system and of the problems in evaluating progress:

> There is no disagreement among nations about the importance of conserving oil or about the contribution that sensible measures of conservation can make to the short- and longer-term health of their economies. This applies as much in the field of transport, which accounts for about a quarter of the oil consumed by European Economic Community (EEC) countries, as in other fields. Where there is less agreement, however, is on the question of how far market forces, allied to appropriate pricing policies should be relied upon to secure the desired objectives of energy conservation, or to what extent these should be supplemented by government policies designed to affect the pattern of supply and demand.
>
> The theme of the present paper is to suggest that great care is needed in interpreting the objectives of energy and economic policies as they are applied to decisions affecting transport.

> It is the concern of the United Kingdom to demonstrate two main propositions in the field of transport:
>
> a. that objectives expressed purely in terms of energy saving may not lead to decisions in accordance with wider economic objectives;
>
> b. that in transport, the effect of measures designed to influence modal split in the interest of energy conservation may not always lead in practice to energy advantages when evaluated over all the modes affected.
>
> It is obvious that "energy-saving at any price" is not likely to be a sensible policy. For example, it has been experimentally demonstrated that it is possible to design a four-wheeled car which will run for 520 kilometres on a litre of petrol. But this is not to say that everyone should adopt this highly expensive and low-performance vehicle as their mode of travel. This rather extreme example shows that policies expressed merely in terms of energy conservation objectives are likely to be very wasteful in terms of total resources. Another way of expressing this is to say that the "shadow price" of energy implied by objectives expressed in this way is likely to be very much higher than its true value, even when based on extreme assumptions about the long-run marginal costs of fuel.[3]

The orientation of this paper, then, is simply to elaborate on the hypothesis that national policy aims expressed solely in terms of energy savings from transportation action may not lead to decisions which are consistent with wider economic considerations and that narrow, modal measures of energy effectiveness in transportation are not useful as sole criteria for major judgments.

Despite the fact that we know the general linkages between energy use and transportation in the United States, our "confidence level" in assessing the future is severely limited, particularly on a national transportation sector basis by at least five factors:

1. Single uniform factors (for example, ton-miles per gallon) have severe limitations in representing the extremely complex relationships involved in transportation and energy. Energy efficiency measurement is very complex and cannot be represented by such single indicators.

2. Generalized assertions of comparative energy efficiencies of various modes tend to obscure the fact that "energy use varies among circumstances; any particular mode is rarely more energy-efficient in all cases."[4]

3. The deregulated market as a decision system for evolving to energy efficiency in our transportation system--and balancing it with other economic effectiveness impacts--is an effective long-run mechanism for achieving national economic growth goals.

4. Useful and credible "packages" of effectiveness indicators for transportation energy efficiency decisions are lacking, and new, more relevant research programs, facilitated by such organizations as OECD, are clearly needed to provide basic investment/performance relationships for member nations.

5. Government and private roles in managing change in transportation system performance and energy conservation need support from more long-term research and information on evaluation approaches.

The above five points are elaborated below.

1. The Use of Single Modal Factors

This point simply cautions against narrow views of complex issues and points to a full analysis of broad economic impacts and performance relationships before major investments in transportation infrastructure are made to save energy. A recent report by the Oak Ridge National Laboratory for the U.S. Department of Energy suggested that since not all aspects of any two modes actually compete with each other, no comparisons should be made at the aggregate modal level.[5] Further, the report suggests that both intermodal and intramodal variations in full efficiencies should be measured in terms of service provided--for freight, including such factors as shipment size, speed, and shipper/receiver convenience, and for passengers, including the volume of passengers and ideally the economic and social benefits afforded by the service.

Single, simplistic modal factors also tend to obscure the indirect costs and benefits of a service or mode in question and neglect the fact that energy conservation actions are not effective if implemented in a fragmented or piecemeal way. In other words, evaluation of the total impact of a series of actions on a broad scale appears to be a more reasonable approach to predicting and monitoring the energy effectiveness of proposed or actual system changes. Again, packages of indicators applied to a total strategy over a wide area of different modes and actions are the only useful way to apply such measures.

2. Energy use varies among circumstances; thus, incremental changes in systems should be evaluated against potential energy savings at a "high macroscale" of analysis.

It is increasingly the whole transportation system or sector that is being related to broad social, economic, and development goals, yet it is rarely possible to reach a balanced perspective of total system performance for decisions on any scale.[6] In practice, this means that evaluation of energy savings can be accomplished most usefully only if compared over time for a series of actions which are intended to act to produce a given service or supply level (freight or passenger) at lower total energy consumption rates. This kind of assessment should be made on a high macroscale, for example, regional, state, or national basis, and not on a narrow urban corridor or modal basis. Both indirect and direct effects need to be monitored in terms of marginal energy conservation potential. For instance, one of the indirect energy effects sometimes overlooked in evaluating alternative strategies is the increase in trip circuity that accompanies some urban options such as ridesharing or shifts to bus or rail transit systems. As a result, the net energy savings may be considerably less than a quick comparison of energy use per passenger-mile traveled might lead one to believe.[7]

The significance of this point, an enlargement of the first, is that in analysis of energy impacts the relevant scale is potentially national in scope. Thus, the focus is on the national transportation sector, not simply on specific elements.

There is also wide agreement that analysis of alternative transportation programs and policies must look beyond inputs and outputs. From the point of view of energy savings, the efficiency of each transport mode (private motor vehicles, buses, trains, subways and suburban trains, and others) depends mainly on trip characteristics and vehicle occupancy.[8] This principle is equally applicable to freight transport as well, since the energy efficiency of freight movements is a function of the economic value of the freight as well as its volume.

3. The unregulated market as a decisionmaking system should be relied upon in the long term to achieve energy efficiency in the transportation sector; Government's role increasingly will be the monitoring and analysis of data and information on how the total system is performing against such broad goals.

Current United States strategies are based on the hypothesis that deregulated energy markets will provide, in the long term, proper incentives to conserve scarce petroleum resources and to develop domestic resources. In the United States, imports have dropped 1.5 million barrels a day since April 1980, while domestic production has increased approximately 600,000 barrels a day. Thus, the strategy appears to be working. In the short term, fuel economy standards will continue to encourage improved vehicle design and generation as the era of controls (in the United States) are phased out.[9] Thus, the (Federal) government will move increasingly to the role of monitoring the market system and identifying trends in transportation service and energy consumption against these projections.

This shift from a managing strategy, based on intended impacts on the system, to a research and monitoring strategy, based on the need to monitor and interpret system developments, requires a major new program of research and information on how to monitor changes accurately and inexpensively. New issues now arise in terms of performance evaluation approaches and to "packages of indicators" which measure overall energy consumption and transportation service relationships. As stated in another Symposium paper:

> The Federal Government should support the development of measures of transportation systems performance and the collection of data describing such measures. This issue is particularly critical in the face of deregulation, as many data bases currently available describing use and prices for transportation systems will no longer be available to agencies or consumers. The lack of such information is likely to lead very rapidly to a radical shift in our ability to even measure the degree to which transportation systems are being utilized, let alone performing in some optimal fashion.[10]

4. Packages of indicators are needed to measure energy effectiveness.

The relationships between transportation and energy are complex and changing, yet there is a continuing need to identify various elements of those relationships. This can be accomplished through the development of "packages of indicators," which specifically address the relationship of energy consumed (direct and indirect) to effectiveness measures, for example, the economic value of a ton-mile or the economic value of a work trip. Identifying these kinds of relationships through indicator packages would accomplish for a whole sector what a recent OECD report on public transport evaluation did for internal efficiency issues in public transport.[11] Governments need to know more about these relationships for two reasons:

1. to prepare for public allocation of scarce energy in a short-fall emergency and
2. to identify areas of further research to be carried on by the transportation industry itself or by government to develop energy efficient technology.

The first objective, the preparation for a system of rationing energy in crises situations, remains an important aspect of public policy in the Western World. The problem is the process of understanding the elements of the transportation and energy relationship and providing public decisionmakers with criteria for allocating fuel to sectors with the highest economic and social benefits, if need be.

The second objective, the identification of further research needed, is simply the process of trying to "separate out" the economic value of various transportation services and outputs in order to understand our consumption priorities and trends and relate them to national objectives.

This is an important but sensitive area of policy research. As stated by Pisarski with respect to passenger demand:

> ... the current evidence seems clear that all modes of transport are underpriced. This leads to the economically determined assumption that we are "over

> consuming" mobility in some sense. Even at this state of generalization, the statement has dangerous overtones. To state that there is over-consumption implies that some portion of travel is superfluous or non-essential, with the further implication that we can somehow separate the "essential" wheat from the non-essential chaff. The normative overtones in this conception are adequate cause for pause and serious reflection. To clarify the issue, using VMT as our measuring rod, we could see VMT as the "effort expended" and some portion of it as a new statistic to measure the "work accomplished," or "end-achieved." We do this implicitly on occasion, without moral violence, when we divide VMT by a given circuity factor to get "crow-flies distance."
>
> An apt analogy may exist with nutrition. Calories per capita is rather universally used as a measure of nutrition throughout the world. It seems to serve well as a rough first measure, especially in developing nations where the value is low. VMT per capita might serve the same function. In the United States, however, nutritionists are more concerned with "a balanced diet" than with adding more calories to the national diet. In fact, they speak of "bloated diets" and "wasteful calories" and speak of the dangers of over consumption of "empty calories." Is the analogy apt? Are we suffering from empty VMT's? And would a more "balanced VMT diet" better serve national health: Who are the "nutritionalists" in transport who know what constitutes "a balanced diet?" Who fills out the prescriptions? Enough of analogies.
>
> Going off in search of evidence of over consumption of transportation in an attempt to decide how much travel is "right" is a high-risk activity. We are getting into the subject area of shaping demand. Such an activity has a demogogic sound to it. The issue loses some of its virulence, but not all, if it is recognized that there is no way not to shape demand. Every supply decision, including "following demand" in fact, shapes future demand.[12]

This proposition simply indicates that whether we favor more or less public intervention or involvement in supply and demand, we had better realize that it occurs simply because government is a factor of long standing in transportation, and our understanding of the relationships is critical.

5. Government and private activity in managing change in transportation system performance and energy should be supported by research and information which establishes a common basis for assessment.

A primary means of assuring Western World capability to handle future energy scarcity is in understanding where we are now. Research is needed to define current transportation sector impacts, such as in energy, and in development of future scenarios which provide the means by which the private sector can respond, both on the supply and demand sides. Measures of effectiveness in energy efficiency will bring about the kind of investment necessary to improve the situation. For instance, O'Sullivan and Metcalf from Ireland point out in their paper for the Symposium that the perception of private auto operating costs may be a major factor in energy inefficiency.[13] Rather than addressing the issue as a regulatory one, the development and dissemination of information on this issue is clearly needed. The objective here is informed user decisions, not control.

Research Issues

In sum, this paper cautions against widespread use of single performance indicators for evaluation of the energy efficiency of transportation systems, and concludes that the current state of the art in such evaluations is not highly developed. There are some basic issues in developing a "package" of energy transportation indicators which might be useful to identify for policy and research decisions at various levels of public and private transportation activity.

The basic proposition of this paper is that energy consumption and energy efficiency are complex issues and cannot be assessed easily. Clearly, the focus for assessing energy efficiencies (as one cost issue in transportation policy) should be a series of performance indicators which measure a wide variety of relationships between energy input and transportation effectiveness at a broad scale of analysis.

Such a package of indicators would improve the state of the art in assessing impacts. The following issues--both policy and technical in nature--should be initially addressed in such a process:

1. Will fuel price levels rise to levels where efficiencies will be automatically assured through market processes? If so, what is the public policy role of evaluation and monitoring of energy efficiency? What is the technical ability of governments to do so?

2. Given our earlier misreading about the rapid growth of world energy consumption as a whole, the continued shift toward oil everywhere, and the rapidly rising volume of American oil imports, what trend monitoring should be conducted, and what technical problems must be confronted?

3. What are the overall trends in absolute and per capita fuel use, and will growth in travel and freight movements be counter-balanced with efficiency gains, especially in autos and aircraft?

4. What account can be made of the effectiveness of transportation systems in judging energy efficiency; that is, how should "payload" value be assigned?

5. What is the best approach to assuring that user and non-user judgments on energy efficiency reflect all conditions relevant to the system's energy cost and performance?

6. How should governments prepare for energy "shortfalls" and fuel allocation decisions? What criteria should be used in establishing priorities and how does energy efficiency enter into the decisions? What institutional and managerial processes should be in place to handle emergencies?

7. What kind of information on energy efficiency should be made available to systems users and what criteria should be used? What is the perception of cost?

8. How should energy efficiency be measured and weighed in establishing specifications for transportation technology and system developments? On what scale? System, vehicle, corridor, urban, regional, national, or international?

9. How should direct and indirect energy costs be accounted for?

10. How do governments make judgments on goals for evaluating progress toward more "energy independence?" What role does the transportation sector play in achieving such goals and how is progress assessed?

These 10 policy issues appear to be central to developing an approach to relating transportation sector performance to energy goals. It is the author's judgment that the current ability of Western governments to answer these questions, from a common technical point of view, is limited because these issues have not been effectively addressed in a policy research program.

Summary

The basic point of this paper is simply to emphasize that governments will continually face problems in understanding current and future transportation/energy relationships. Governments need to focus on establishing the forum for a competitive economy by producing information on the long-run impacts of current trends. This includes support for policy research to develop performance evaluation approaches which meet a wide variety of needs in a free market economy. This research needs to be international in character and scope simply because all Western developed countries face essentially the same issues and need to communicate with each other toward common action.

NOTES

1. ECE Report by the Executive Secretary on the Commission's Activities and Implementation of Priorities in 1980, Washington, D.C., February 1981.
2. Ibid., p. 6.
3. ECE Inland Transport Committee, Ad Hoc Meeting for Reviewing Transport Development Trends, 1981, p. 23.
4. U.S. Congressional Budget Office, Financing Waterway Development: The User Charge Debate, Washington, D.C., July 1977, p. 17.
5. A. B. Rose and E. J. Reid, "Energy Intercity and Related Parameters of Selected Transportation Modes: Freight Movements," Oak Ridge National Laboratory, June 1979, pp. 2-6.
6. Bruce T. Barkley, et al., OECD Road Research, "Urban Public Transport: Evaluation of Performance," Paris, 1980, p. 5.
7. Donald Symmes, "The Federal Highway Administration's Role in Petroleum Conservation," June 1979, p. 6. (Unpublished paper.)
8. Burkhard E. Horn, "Worldwide Research and Urban Transportation Issues," Traffic Quarterly 35 (January 1981): 41.
9. National Transportation Policy Study Commission, National Transportation Policies Through the Year 2000, Final Report, July 1979, p. 330.
10. David Hartgen, "Energy Conservation in Transportation Systems Performance," New York State Department of Transportation, p. 8.
11. Ibid., OECD Road Research Report.
12. Alan E. Pisarski, "Preserving Mobility in an Energy Scarce Society," Transportation Seminar, Princeton University, October 1979, pp. 11-12.
13. Donal O'Sullivan and A. E. Metcalf, "Energy Conservation in Transportation, Land Use Planning, and Management."

TRANSIT'S ENERGY EFFECTIVENESS

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Abstract

Energy expended on urban transportation now constitutes about 13% of all energy consumption in the United States, and this proportion is growing. Because automobiles account for most urban travel, it would appear that significant energy savings would occur if policymakers could succeed in shifting a significant amount of travel to more fuel-efficient transit. However, most analysts discount such potential savings for several reasons. Some conclude that transit's share of travel is so small that the supply of transit cannot be expanded to accommodate a significant share of traffic at least for the foreseeable future. Others conclude that even if transit supply could be expanded, motorists would not shift to transit. Still others argue that even if motorists did shift to transit, transit's energy saving potential vis-a-vis the automobile is so insignificant that large energy savings would not occur.

This paper analyzes the second two arguments and finds they can neither be refuted nor supported based on existing information. Many data omissions and improper analytical techniques have led to premature conclusions that transit is ineffective in saving energy in the long run. Little is known about indirect energy related to automobile travel and its short and long-term variability with respect to changes in vehicle miles traveled. Most studies assume this energy to be small and not variable, but if these assumptions are wrong, transit may be very energy-effective. The literature says little regarding the energy intensiveness of rail transit with respect to the proportion of designed service actually supplied, or with respect to the capital intensiveness of the system. Most studies have treated highly capital intensive systems offering a supply of service far below that designed. Treatment of less capital intensive systems more fully utilized would yield different results. It is generally assumed that one automobile trip would translate into one transit trip, but there is reason to believe one auto trip might result in less than one transit trip, given the same level of mobility. Almost all "typical situational" analyses of transit's energy effectiveness focus on the suburb to center city trip, which is such a specialized type of

travel (even for transit) as to be meaningless in terms of general conclusions.

The reader may make reasonable assumptions about these ambiguous areas. One set of assumptions will show transit development to be an ineffective energy saver in the long run. Another equally valid set will show transit development to save large amounts of energy. Neither set can be disputed until travel and energy characteristics in transit intensive areas are contrasted to comparable areas that are not transit intensive. Until such work is satisfactorily performed, policymakers are cautioned against making generalized statements about the energy efficiency of different modes.

Introduction

The large proportion of national energy consumed by urban transportation activities has led to numerous studies seeking conservation measures. It is widely believed that increased public transportation would save energy, but professional studies conclude that improving transit is an ineffective energy-saving strategy. Are these professional conclusions justified? Should they be allowed to influence public policy concerning the supply of transportation service? This paper examines the data and analytical techniques used and questions the conclusions. Omissions and inappropriate analytical techniques leave the question of transit's ability to save energy in the long run still unanswered.

Existing Thought on Transportation Energy Consumption

Passenger transportation in urban areas is a large and rapidly growing component of national energy expenditures, suggesting that this is a productive area for energy conservation measures. In 1976, all transportation activities consumed about 2.03×10^{19} joules (19.3×10^{15} Btu) of energy, or about 26% of the United States total energy expenditure and 56% of all refined petroleum products.[1] Transportation energy use had grown 123% since 1950, and the proportion accounted for by urban passenger transportation increased from 22% of the transportation total in 1950 to 50% in 1977.[1] The large increase in the urban travel share of energy consumption is attributed to increased urban travel, a shift of travel from transit to autos (which consume more energy per passenger mile) and an increase in the amount of energy required to move one passenger mile for any given mode. For example, transit carried almost 20% of the 350 billion passenger miles of U.S. urban travel in 1950, but only 3.5% of the 1,077 billion passenger miles in 1978.[2] Over almost the same period, the energy required to move one passenger mile by auto, bus, and rail increased 13%, 33%, and 9%, respectively.[3]

Why Transit is Thought to be Ineffective

While the share of national energy consumed by urban transportation is large and increasing, many analysts have concluded that public transportation cannot or should not be used to achieve energy savings. Their reasons can be grouped into three areas.

The first area concerns the small share of travel accounted for by transit. Currently accommodating less than 3.5% of urban travel, transit would have to experience unheard-of patronage increases in order to have an impact on energy usage. For example, a doubling of transit patronage would save only about 1.26 x 10^{17} joules per year (52,000 barrels of oil per day), or 0.6% of all energy being expended on transportation in the United States in 1975. It is thought that a doubling of transit patronage would require years of effort, even to assemble the necessary buses and rail cars, managerial talent, and work force; so at best, a transit strategy would be a long-term strategy.[4]

The second area is concerned with whether policymakers have the ability to induce a shift of auto travel to transit, and whether such a shift would be cost-effective. While passengers who left transit during the years of decline switched to automobiles, many observers believe that the reversal of the downward transit patronage trend occurring at present does not mean that people are switching back from autos to transit. A doubling of transit patronage resulting from improved service supply would therefore waste energy, because the new transit passengers would not be people switching from less energy-efficient automobiles, but would be (presumably) the traditional transit passengers riding more frequently. The reasoning behind this observation is that transit is simply an inferior good to automobile travel in most environments.[5]

The third area concerns the energy savings that would result if a large share of travel did shift from autos to transit. Most analyses have concluded that the energy required to move one passenger mile on rail systems is only marginally less than that for a typical automobile of today and more than that for the fuel-efficient compact cars that will characterize the U.S. fleet in the next five years. The performance of buses is only somewhat better today, and the new buses coming into use are significantly less fuel efficient than the old. Thus, the popular conception of transit as being more energy-efficient than automobiles is not true according to this line of thought.[6]

Inconclusiveness of Arguments

The first argument cannot be debated. Even if transit usage trends are not reversed, and that is not yet clear, many years will be required for transit to recapture a significant volume of traffic. Thus, consideration of transit as an energy-saving strategy has to be in the context of the long term. Short-term considerations involve nothing more than making more intensive use of facilities and vehicles already in existence.

However, the fact that transit now accommodates such a small share of the urban travel market indicates that it can produce large long-term energy savings, if policymakers can induce a large modal diversion to transit through their control of transportation infrastructure, and if transit is in fact significantly more energy efficient than the automobile fleet.

The second and third arguments state that neither of these two conditions can happen. However, the arguments contain inadequacies that need to be addressed in order to either verify, reject, or modify conclusions regarding the ineffectiveness of transit as a long-term energy strategy. We describe these inadequacies in reference to Table 1, which presents the most current information from the literature on transit and automobile energy consumption.

Missing Data

Table 1 immediately reveals the absence of many crucial pieces of data. Without such data as the amount of energy used to maintain automobiles, or to heat, light and power, such ancillary facilities as gas stations, home garages, auto show rooms, and parts supply stores, as well as to construct and maintain highways and parking facilities, the total energy per passenger mile characteristic of the automobile mode cannot be determined.

Also unknown is the degree of variability of all these factors with respect to a change in vehicle miles traveled. For example, if vehicle miles traveled are reduced by 10%, does the amount of energy characteristic of these ancillary activities go down by 10%, more than 10%, less than 10%, or remain constant? If there is a change, does it take place immediately, after a year, or after ten years?

If all of these additional factors are small, then conclusions about the energy ineffectiveness of transit tend to be corroborated. However, if they are large, then the conclusions may not be valid. For example, the traction energy necessary to propel a 27.5 miles per gallon auto is 3.2 MJ per car kilometer (Table 1). If the total energy per car kilometer, taking into account the above-mentioned factors, is only marginally greater than this, then the auto is about as energy-efficient as transit. If the other factors result in a doubling of the auto's total energy per car kilometer to 6.4 MJ, the auto uses considerably more energy per passenger kilometer than some types of transit. In fact, in comparison to the Bay Area Rapid Transit (BART) with a full service supply, this factor reduces the time to repay BART's construction energy from over 500 years to less than 40 years.[7]

The sensitivity of total energy per passenger kilometer to the intensiveness of usage of a rail line is shown in Table 1. Operating energy and construction energy intensiveness is influenced by the amount of service supplied in relation to the amount of service for which the system is designed. Some past analyses have not taken note of this characteristic.[8] They have concluded that a system's patronage is unlikely to rise, because they observe that practical occupancy is unlikely to exceed the already achieved 20 to 25 passenger miles per car mile, while they make the implicit assumption that car miles will not increase. However, car miles might indeed increase. For example, BART's average occupancy of 21.4 is little different from the 24.9 of the intensely utilized New York system[9] or rapid transit system averages. The

Table 1

WHAT WE KNOW ABOUT TRANSIT ENERGY EXPENDITURES (1)

System	Energy in Megajoules (MJ) Per Vehicle-KM									
	Traction	Maintenance	Station & Other	Total Line Haul	Vehicle Construction	Total Operating	System Construction	Total Energy	Average Occupancy	Total Energy per Passenger-KM
BART-25% Service	40.6	6.1	29.5	76.2	1.1	77.3	100.7	178.0	21.4	8.3
BART-50% Service	40.6	6.1	14.8	61.5	1.1	62.6	50.3	118.9	21.4	5.6
BART-100% Service	40.6	6.1	6.9	53.6	1.1	54.7	23.4	78.1	21.4	3.7
NY Subway	38.6	5.1		43.7	?	?	?	?	24.9	?
Chicago Elevated	32.1	?		?	?	?	?	?	?	?
SD LIGHT RAIL (2.4 Million Car Km/Yr) (Double Track Facilities Capable of much more Intensive Service)	26.8	2.1	.9	29.8	?	?	19.1	?	?	?
COMMUTER RAIL (Chicago Gallery Service)	137.1	?	?	?	?	?	?	?	52.5	?
BUS-4.5 mi/gal	21.8	?	?	?	0.6	?	?	?	11.5	?
BUS-2.8 mi/gal	35.1	?	?	?	0.6	?	?	?	11.5	?
AUTO-14.5 mi/gal	6.3	?	?	?	0.8	?	?	?	1.3	?
AUTO-27.5 mi/gal	3.2	?	?	?	0.5	?	?	?	1.3	?

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(1) Figures are derived from: Lave, Charles A. "Rail Rapid Transit and Energy the Adverse Effects." Transportation Research Record, NO. 648 (Washington, National Academy of Sciences, 1977). Table 2, p. 16, except as follows:

a. BART Constructon Energy Taken as 78x10^{15} Joules (78PJ), from Williams, Gwynne Pierce, Jr., Energy Costs of Heavy Rail Transit Construction. Masters Thesis in Engineering, Princeton, N.J., 1978, pp. 60-61.

b. San Diego Light Rail Construction Energy per KM Taken as 1/9 of BART'S, Consistent with the Constant Dollar Cost Ratio of the Two Systems.

c. BART Operation Energy from Healy, Timothy J. Energy Requirements of the Bay Area Rapid Transit System. Report Prepared for the California Department of Transportation, Sacramento, and also from Peat, Marwick, Mitchell. Analysis of BART'S Energy Consumption for Interim Operations. Report Prepared for UMTA, U.S. Department of Transportation, Washington, D.C., 1975.

d. New York and Chicago Information from Healy (Above) and Holden, W.H.T. in "Discussion of Rail Rapid Transit, the Adverse Effects," Transportation Research Record No. 648. (Washington, National Academy of Sciences, 1977), p. 21.

e. San Diego Light Rail Information from phone conversation with Maurice Carter, Director of Planning and Operations, San Diego Metropolitan Transit Development Board, 17 April, 1981. Figures are estimates for a level of service of 2.4 million car kilometers per year, derived from on-going testing of the 25.6 kilometer long line, now nearing revenue operation.

f. Commuter rail figures from Walbridge, Edward W., "Energy Consumption, Pollutant Production, and Dollar Costs of Diesel Suburban Commuter Trains," Transportation, September, 1976, 5(3), pp. 285-307.

(2) Figures are presented as energy used by power plants or refineries. Data originally in form of power used by transit systems was divided by .31 to account for energy lost in conversion and transmission.

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average occupancy for BART does not suggest a system which is having difficulty attracting patronage as is often alleged, but one which is operating at close to the practical limit allowed by the supply of service currently operated. That supply, about 3.3 billion car kilometers per month, is less than half of the intended supply of service for the existing facilities. A not unreasonable assumption is that BART's supply of service, and hence its patronage, will more than double once technical difficulties are resolved.[10] Total energy per passenger kilometer would then fall by 66% (Table 1). This eventuality would favorably affect the energy effectiveness of BART.

Inappropriateness of the Single Passenger-Kilometer Based Analysis

Some transportation energy analyses are based upon the energy intensiveness of a passenger kilometer produced by several representative transportation modes. Energy that would be saved or wasted by producing one additional passenger kilometer on that particular mode may be estimated if assumptions are made about where the passenger kilometer would be produced if the mode in question did not exist.[11]

This type of analysis contains the implicit assumption that trips transferred from autos to transit will be on a one-to-one rate of substitution. This may not be the case. For example, suppose there is an initial state in which 100 trips are made by automobile. Now, suppose that the automobile is entirely replaced by transit. Are we to suppose that there are now 100 trips made by transit? Probably not. The rate of substitution from auto to transit may be less than one-to-one because of the chauffeuring effect characteristic of a component of automobile travel, as well as perhaps other factors inducing automobile trip making. The chauffeuring effect is typically disregarded in the literature, but Sullivan believes it may be significant.[12] An example of a trip of a child from home to school and return will serve to illustrate this effect. If the mother drives the child, six person trips are produced. If the child makes the trip entirely on his own on transit, two person trips are produced. Thus, one auto trip translates into .33 transit trips for the same level of mobility. Wherever this type of relationship holds, analytical techniques that assume a one-to-one rate of substitution for person trips for auto to transit will underestimate the energy-saving potential of transit.

Inappropriateness of Suburb to Downtown Analysis

Another analytical technique for assessing transit's effectiveness is the use of a "typical" suburb to center city trip as the "typical" trip.[13] This technique may minimize the energy-saving role of transit because it confines the analysis of transit to a highly specialized segment of total metropolitan travel implying that transit works less effectively for the shorter trips, which are the least energy efficient for automobiles. The scope for transit's energy-saving potential for the short, community level trip is minimized in this type of analysis.

Suburban to CBD transit services are frequently energy ineffective, because of "dead-heading" and low reverse commuting loads. However, transit systems designed to compete for the totality of metropolitan travel have succeeded in capturing a much larger share of travel than specialized-downtown-oriented systems.[14] The energy savings of such systems have not been studied. They may be far more significant than those heretofore attributed to transit. There is a need for a broader model of transit travel used to calculate energy savings.

Inappropriateness of Average or Typical Situations

Modal comparisons of energy intensiveness are often based on average values for a number of systems,[15] or on a representative "typical" system.[16] Neither type of analysis can yield generalized conclusions where costs are so heavily influenced by site-specific considerations. An ideal right-of-way may be available in one locality making the cost of a heavy rail system far below the national average; on the other hand, another locality may have to pay considerably more to achieve a similar level of service. BART is often portrayed as being typical of modern heavy rail systems. It is typical of systems containing a considerable amount of subway and elevated sections. A fair conclusion from an analysis of BART might be that rail, bus, or any other special purpose systems should not be built containing so much tunnel and elevated structure, particularly with stations incorporated into such structures, unless they are intensively utilized. However, rail systems that, for example, use existing railroads or perhaps convert existing freeway lanes might be highly energy efficient. San Diego, for example, made the policy decision to reject a BART-type system running over an arterial street through the center of demand of a particular corridor. Instead, San Diego has built a rail transit line out of an existing parallel railroad less ideally situated with respect to demand, but having a cost of $1.1 million dollars per kilometer in contrast to BART's $10.8 million (1967 constant dollars). The construction energy intensiveness of the San Diego system is probably also about 9-fold less than BART's.[17]

Will Motorists Switch to Transit?

The largest unanswered question regarding the consideration of transit as an energy saving strategy is the degree to which motorists will switch to transit as a result of improved transit service or worsened auto and highway supply. Transit's modal share of metropolitan travel, while less than 3% in most North American areas, is in some areas much higher--in the range of 15 to 20%. Because automobile ownership in these areas is as high or higher than in those areas where transit ridership is very low, a reasonable conclusion is that in these high transit ridership cities, people who have the choice of driving are voluntarily choosing to make use of the transit system to fulfill a significant part of their daily travel requirements.[18] In many American cities this choice is not available for general metropolitan-wide travel, although transit may be useful for certain specialized trips.

Even in generally low transit ridership areas, examples can be found of individual transit lines that have attracted significant ridership from the automobile. In the Los Angeles area, the San Bernardino busway's patronage has grown from approximately 1,800 trips per day at the time of the busway's opening in January 1973 to 22,500 per day in 1980.[19] A 1975 survey showed that 50% of the then 14,500 daily users previously drove alone.[20] This percentage is higher today because of the higher bus availability and the absence of other bus services from which passengers could have been diverted. Also, in Southern California, intercity train service between Los Angeles and San Diego has experienced passenger increases from an average of 900 per day in 1975 to over 3,200 per day in 1980. Business-related travel increased from only 27 per day in 1975 to over 1,000 per day in 1980. Surveys show that 65% of these travelers would drive if the train were not present.[21] The primary difference between low transit usage and high transit usage areas is that the high usage areas manage to connect more pairs of origins and destinations with relatively direct transit service which is time competitive with auto travel.

A related question is to what degree high transit utilization in these areas is attributable to governmental decisions regarding transit and highway system supply. Even less is known here. However, a recent international study on transit usage characteristics discovered that while, in general, transit usage declined while automobile ownership rose, there are many significant exceptions to this rule. The study concludes that the exceptions (as well as the rule) might be determined by governmental policies on transportation service supply.[22]

There is a need to research the characteristics of those North American metropolitan areas where transit usage is significantly higher than other areas. Answers might be forthcoming to many of the unanswered questions raised in this paper. In particular, two questions need to be addressed:

1. Are passenger miles traveled per capita greater or less than those in a low transit usage city; that is, can it be concluded that transit is resulting in additional travel in the high usage cities, or is it substituting for automobile travel?

2. What is the total energy per capita and transportation energy per capita in a high transit usage metropolitan area in contrast to that in a comparable low usage area? Can differences be attributed to the presence or absence of transit?

Even if rigorous study concludes that transit does indeed substitute for automobile travel in some selected metropolitan areas, the question is still raised as to whether transit can substitute equally well for automobile travel in metropolitan areas where usage is very low today, that is, less than 3%. Furthermore, what would the energy consequences be? Some authors conclude that transit cannot be effective in the currently rapidly growing U.S. metropolitan areas because of their lower densities.[23] However, densities in urbanizing areas of the Southwest may be greater than commonly is supposed. For example, urbanized Los Angeles County excluding the mountains has the highest residential densities in the United States outside of New York and Philadelphia. To the extent transit service is supplied, and allowing for time lags, the public appears to utilize transit service in at least some of these newer areas as much as they use it in more traditionally transit-oriented areas. The answer to the question of whether transit will be used in newer areas depends upon whether adequate service is supplied.

The question of supply is related to the question of financing. That question is beyond the scope of this paper except to note that, to a certain extent, the decline of transit was a function of underpricing of road facilities in the United States since the 1920s. Underpriced roads not only resulted in a greater traffic diversion than would otherwise have been the case, but the resulting depressed transit traffic resulted in transit offering a lower quality of service. The process was cyclical over a 50-year period. Every year the "quality gap" between transit and highways widened, resulting in transit being less and less of an alternative for the majority of residents. Roads in the United States are still underpriced, paying neither property taxes, depreciation, nor return on investment. In addition, peak hour commuters do not pay for the expansion of the road space they demand.[24] Requiring road users to pay their fair share of the cost, or giving transit a subsidy equal to it in order that the public might be able to make decisions maximizing their best interests, might supply an answer to both the energy and financing question.

One additional point might be made regarding financing. Much of the existing highway system will wear out within the next 20 years. Its replacement in kind will result in vast financial (as well as energy) expenditures. Opportunities exist for managing its replacement so as to provide competitive transit.

In terms of energy implications, the expansion of transit in the short run in an initially low-usage area would probably consume more energy than it would save, unless there would be a clear-cut substitution of new transit facilities and services for highway facilities and services (such as replacement of a highway rebuilding program with a transit program). The reason is that energy expenditures for the highway sector occur in activities such as gas stations, garages, parking lots, auto supply stores, police services, and traffic courts, as well as more direct expenditures.[25] A sudden emphasis on transit will not result in reductions to many of these sectors immediately. Transit energy expenditures would be an additional energy burden. The passage of time is needed before resources slowly transfer out of these areas in proportion to travel shifts.

Pulling It All Together

To illustrate the sensitivity of transit as an energy saving strategy to assumptions regarding the questions that have been raised, we have prepared Table 2. Table 2 is predicated on an hypothetical metropolitan area with a population of one million, with each resident making four trips per day. Most trips are by automobile and have an average length of 11.3 kilometers. In addition, however, another 750,000 daily passenger kms are made on transit (about 100,000 revenue boardings per day), and 75,000 passenger kms per day are consumed in walking. These conditions are fairly typical of many North American cities. If we assume the average energy expenditure for automobile travel is 4.9 megajoules per passenger kilometer (this assumes a heavy load of

TABLE 2

SENSITIVITY OF TRANSIT ENERGY SAVINGS TO MODAL DIVERSION

	Passenger Km Per Day					Energy Per Day	
Condition	Auto (1)	Transit (2)	Walk	Total	% Transit	Total (joules)	Savings (joules)
Initial	45,161,000	750,000	75,000	45,986,000	1.6	2.24×10^{14}	---
Transit Improved I	44,786,000	1,500,000	59,000	46,345,000	3.2	2.24×10^{14}	0
Transit Improved II	30,391,000	7,500,000	295,000	38,186,000	19.6	1.71×10^{14}	$.53 \times 10^{14}$

(1) 27.5 mpg auto assumed; traction energy of 3.2 MJ/car km; total energy 6.4 MJ/car km; occupancy of 1.3

(2) 4.5 mpg for assumed; traction energy of 21.8 MJ/car km; total energy of 33.6 MJ/car km; occupancy of 11.5

ancillary energy on the traction energy of a 27.5 mpg auto), and the average energy expenditure for transit travel is 2.9 megajoules per passenger kilometer, then this hypothetical situation results in a daily average energy expenditure of 2.24 x 10^{14} joules (the equivalent of 1,560,000 gallons of gas per day, although some of this energy would be consumed as electrical energy, or used in construction and maintenance of auto-related facilities.)

What happens if we improve transit? Under our first assumption, transit usage is doubled, and one-half of the new passenger miles are diverted from automobiles. Most of the rest are induced riders, although some are diverted from walking. Given these assumptions, which many would consider plausible, energy use would stay just about the same.

However, under a different assumption, transit usage is increased 10-fold over a period of many years. Almost all of the new riders come from automobiles, and the rate of substitution is 1.0 auto trips producing 0.5 transit trips. In addition, the larger transit emphasis results in a much larger degree of walking. Under these assumptions, which are also plausible, a daily energy savings of .53 x 10^{14} joules (366,437 gallons of gas) results. This is a 24% savings and is significant.

Of course, these results would be much less impressive if the average energy expenditure per auto passenger km turns out to be less than 4.9 megajoules for a 27.5 mpg car but, on the other hand, the average energy usage might turn out to be more. This example serves to illustrate the need for answering this and the other open questions presented in this paper.

NOTES

1. Shonka, D. B. ed., Transportation Energy Conservation Data Book: Edition 3, #ORNL-5493 (Oak Ridge, Tennessee: Oak Ridge National Laboratory, Regional and Urban Studies Section, Energy Division, February 1979), Table 2.4, pp. 2-10, and Table 2.6, pp. 2-12.

2. Calculated from data in: American Public Transit Association, Transit Fact Book, (1978-79 ed.) (Washington, D.C.: 1979), p. 15; Shonka, Transportation Energy Conservation Data Book, Table 2.6 (p. 2-12); Hirst, Eric and Stuntz, Mayo S. Urban mass transit energy use and conservation potential, Energy Systems and Policy, 1976, 1(4), p. 397; and U.S. Department of Transportation, Federal Highway Administration, Highway Statistics: 1978, (Washington, D.C.: Government Printing Office), using 6.9×10^{11} annual automobile miles with an average load factor of 1.5.

3. Hirst, "Urban Mass Transit Energy Use", Energy Systems and Policy, pp. 392-397.

4. Ibid., pp. 403-404.

5. Lave, Charles A., Transportation and Energy: Some Current Myths. #UCI-ITS-SP-79-1 (Irvine, California: University of California, School of Social Sciences and Institute of Transportation Studies, 1979), pp. 2-5 and 9-10; Garrison, William L. & Jones, David W., Energy Conservation in Urban Transportation, #UCB-ITS-RR-79-15 (Berkeley, California: University of California, Institute of Transportation Studies, October 1979), pp 1215.

6. Lave, Charles A., "Rail Rapid Transit and Energy: The Adverse Effects," in Environmental and Conservation Concerns in Transportation: Energy, Noise, and Air Quality, Transportation Research Record #648 (Washington, D.C.: Transportation Research Board, 1977), pp. 14-18; Lave, Transportation and Energy: Some Current Myths, pp. 5-9.

7. Lave, Rail Rapid Transit and Energy, TRR #648, pp. 14-18. This example uses construction energy for BART as shown in Table 1, rather than that used in the article.

8. Ibid., pp. 14-18.

9. Holden, W. H. T., "Discussion [of Lave, Rail Rapid Transit and Energy]" TRR #658, p. 21.

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13. System Design Concepts, Inc. . *Urban Public Transportation and Energy*, pp. 1-9; Henderson, Clark, *Energy Economy Study Methods and Cases*. Prepared for the U.S. Department of Energy under Contract #EY-76-C-03-1176. (Menlo Park, California: SRI International, July 1979).

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15. System Design Concepts, Inc. *Urban Public Transportation and Energy*, pp. 11-39.

16. Lave, Rail Rapid Transit and Energy, *TRR #648*, pp. 14-18.

17. Mitric, Slobodan. "Comparing Modes in Urban Transportation." In *Transportation System Evaluation Techniques*. (Transportation Research Record #639). (Washington, D.C.: Transportation Research Board, 1977, pp. 19-24.

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20. Ibid., p. xii.

21. California Department of Transportation, Division of Mass Transportation. *Amtrak San Diegan Passenger Survey*, (Sacramento, June 1979), p. 16; p. 18; also, Southern California Association of Governments. *San Diego-Los Angeles Corridor Study, Phase 11B Travel Demand Analysis* (Draft), February 1976, pp. 9-13.

22. *The Demand for Public Transport: Report of the International Collaborative Study of the Factors Affecting Public Transport Patronage*. (Crowthorne, England: Transport and Road Research Laboratory, 1980, pp. 400-403.

23. Garrison and Jones, *Energy Conservation in Urban Transportation*, pp. 12-15.

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METHODS OF CALCULATION CONCERNING ENERGY CONSUMPTION IN THE FIELD OF TRANSPORT

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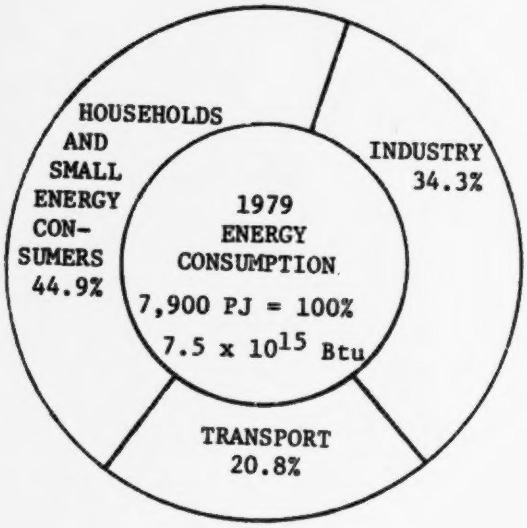
Methods of calculating values of energy consumption, in my opinion, always depend on the energy situation in which they are conceived and applied. For this reason, I wish to give you at first a rough outline of the energy situation prevailing in the Federal Republic of Germany; in particular, the energy situation of the transport consumer sector, followed by an indication of generally applicable criteria which I consider necessary for the evaluation of energy consumption calculations in the field of public transport. Finally, I shall describe some of the procedures used in the Federal Republic and the method of their evaluation.

Net Energy Consumption, 1979

Figure 1 shows the breakdown of net energy consumption in the Federal Republic of Germany in 1979, amounting to 7,900 petajoules (PJ). The transportation sector in the Federal Republic of Germany accounted for 20.8% of energy consumption.

FIGURE 1
BREAKDOWN ACCORDING TO SECTORS OF CONSUMPTION



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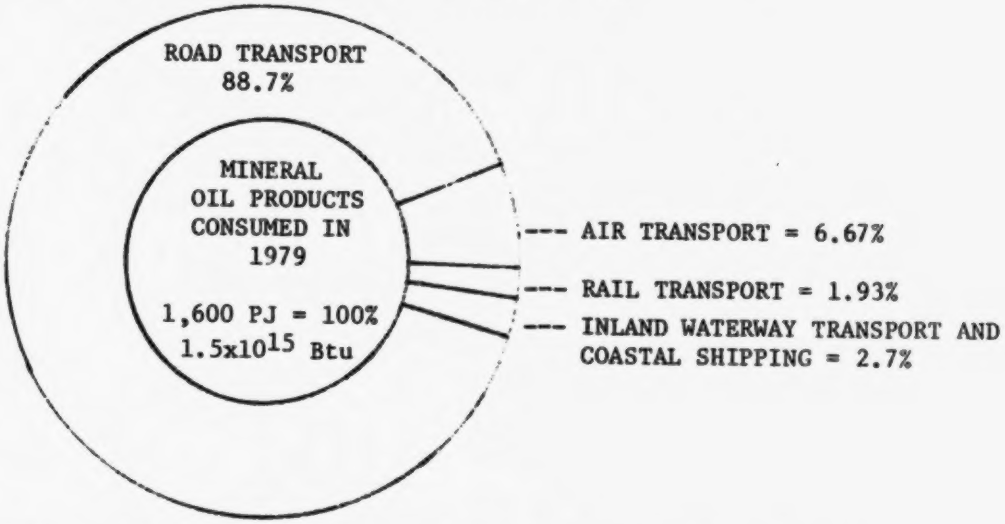
In detail, the consumption of oil products for transportation can be broken down as follows:

FIGURE 2
CONSUMPTION OF OIL PRODUCTS BY TRANSPORTATION



Road transport with a share of almost 89% and air transport with a share of approximately 7% thus require more than 95% of the oil products. Nevertheless, it is worthwhile to think about the small shares required by rail transport and inland navigation, as may be seen in Figure 3.

Please note the railways' relatively high share of goods transport in the Federal Republic of Germany. Additionally, 82% of all ton-kilometers are carried by the German Federal Railways by means of electrically operated trains. This technological progress results in a trend of energy consumption which deviates strongly from that of the other transportation modes.

General Criteria for Calculation Methods

I shall now describe the generally valid criteria to be applied to statistical surveys and methods of calculating consumption so that they may be used, from our viewpoint, for public planning and assessment.

The first criterion is something which may be defined generally as "systems thinking." For example, the truck traffic as a whole need not be examined because average values for this comprehensive sector would certainly be of too global a nature, but rather examinations should be based on the consideration of transport chains, which--typified and classified into the categories transshipment and transport steps--will give a more precise and more meaningful picture of the actual transport situation. This postulate is not very erudite, indeed, but it should be constantly kept in mind. Without explanatory side conditions and without reference to the distance and level of service, the argument, for example, that the bus, with

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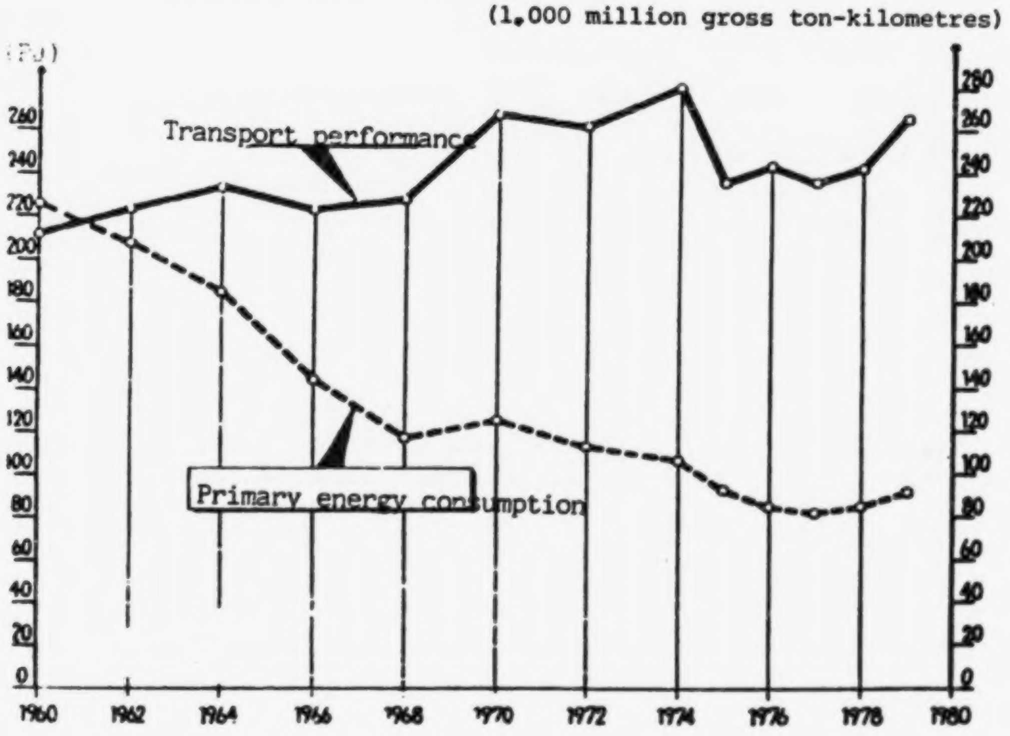
respect to energy consumption, is four times as economical as the passenger car, is worth just as much as the paper on which this statement was written. I believe that an effective method of calculation should include all side conditions relevant to a transportation system and to its specific energy consumption requirements, such as travel speed, distance, and in the case of public transportation, the frequency of service. Time and again attempts have been made to include in these considerations the energy used for manufacturing vehicles and for construction and maintenance of the infrastructure; up to now, however, these studies have been rather disappointing with respect to significance and preciseness.

FIGURE 3
TRANSPORT PERFORMANCE OF THE GERMAN FEDERAL RAILWAYS



For a country like the Federal Republic of Germany, which can cover just 5% of its requirements from domestic oil wells, it is of vital necessity to base all energy considerations on the overall supply and use of primary energy. Conclusions concerning export problems, for example the current

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account balance, and concerning the potential availability of the source of energy can only be drawn in relation to this overall supply and use of primary energy. In my opinion comparative considerations on the energy consumption by end-users would therefore be reasonable only if applied to similar propulsion systems or in the case of estimates of the occurrence of emissions in heavily burdened urban areas.

Other criteria of assessment which I should like to mention are the following:

- concurrence of data recording,
- independent processing,
- indication of the permissible scope of interpretation for diagrams, and
- careful selection of side conditions and factors of influence for trend analyses and forecasts.

Precisely the latter should not be underestimated; in retrospect, forecasts quite frequently only prove the fundamental right of analysts for errors.

In summary, the criteria, which in my opinion are generally applicable to methods of calculating energy consumption, may be outlined by the following catchwords:

- system thinking (transport chains),
- reference to primary energy,
- exactness of data recording and processing, and
- prevention of misinterpretation through indication of the scope of interpretation.

In the following, I should like to acquaint you with a method used in the Federal Republic of Germany which is also evaluated in the Federal Ministry of Transport.

Studies Carried Out on Behalf of the Federal Ministry of Transport

A procedure used to determine energy consumption in the field of transport has been chosen for the study carried out by the Technical University of Aachen (Rheinisch-Westfalische Technische Hochschule Aachen).

For the purpose of this study, existing vehicles (including inland waterway craft) are classified according to their weight and thus are typified to a certain degree. Each typical vehicle size is coordinated in a compensating calculation with typical values of energy efficiency for propulsion and typical modes of operation. The modes of operation, in turn, comprise the following factors of influence:

- average utilization;
- mean travel speed, including all necessary stops;
- mean transport distances;
- frequency of transshipment (in the case of goods transport);
- influence of routes (topography) and other factors of influence.

The results of these calculations are presented for all variables in passenger transport in such a manner that specific energy consumption is plotted as a function of the degree of utilization of each vehicle concerned. The presentation as a function of the degree of utilization equally applies to goods transport, with the degree of utilization in terms of weight being used as degree of utilization for the vehicles. We are quite aware of the inaccuracies involved, as far as the carriage of very light and very bulky goods is concerned, but they are unavoidable in view of the available data. Since this fact applies to almost all systems of goods transport, with the exception of pipelines, we do not think that disregarding these drawbacks will have a detrimental effect.

The method of Technical University of Aachen was applied for the first time in 1976, and since then it has been refined and actualized. At present, the study is again being revised with the aim of ascertaining the latest figures on the energy consumed in the Federal Republic of Germany in the field of transport. This procedure has in the meantime been repeatedly compared with the calculation methods of the Deutsche Bundesbahn, with those of Lufthansa, and with other available methods of calculation, and it showed extensive conformity of data. As far as comparable items are at all available in the field of private transport, for instance, records of large forwarding agencies, bus enterprises, etc., conformity of data has also been found. (This study will be completed in May 1981 so that it will be possible to provide new and more recent data when this paper is presented.)

Other studies, which to some extent have been carried out on behalf of the Federal Ministry of Transport, dealt with other issues, for example:

- influence of the transformation of energy in traffic on the micro climate of urban agglomerations;
- corridor calculations for the assessment of the overall economic benefit of canal construction;
- energy-economic influence of the construction of bypass roads.

Since these calculations only concern individual transport lines or locally limited areas, I do not want to deal with them in detail in this connection.

Conclusion

The problems associated with calculations of energy consumption by transport generally have been solved. However, problems continue to exist with regard to the traffic infrastructure as well as to the values of energy consumption caused by the construction of traffic installations.

As far as the transport operation proper is concerned, it may be assumed that the "major problems" are satisfactorily dealt with in an ABC analysis. Gaps remaining with respect to the determination of additional requirements for transshipment processes still need to be filled.

The exclusive reference to the overall supply and use of primary energy should be regarded as a clear attempt to indicate the dependence of individual transport sectors on the energy resources. It may well be that a country without any significant oil wells of its own, for example the Federal Republic of Germany, in the future will be faced with the necessity to replace the oil by other primary energies in the field of transport, even if this causes a higher rate of consumption of primary energy. What I am thinking of is the utilization of synthetic petrol, hydrogen, methanol, or electric energy by road transport.

I hope that I have been able to give you a general idea of the methods used in the Federal Republic of Germany for the determination of energy consumption in the field of transport.

ENERGY SITUATION OF TRANSPORTATION SYSTEMS IN SPAIN

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The measurement of savings in transportation's energy consumption should be a policy goal of any energy or transportation agency. This is true not only in urban areas but throughout the country. In developed countries, transportation accounts for a large share of the total energy consumed and consumes an even greater share of liquid fuels. Petroleum has become, in western countries, one of the main imports. In Spain, petroleum accounts for 60% of all import expenses, where the transportation sector requires 20% of the total energy consumed in the nation (Figure 1).

The transportation sector consumes one-third of all liquid fuels consumed in Spain. This critical level of consumption suggests the urgent necessity of implementing any measures needed to improve the energy efficiency of the transportation system. This paper will examine the Parking Regulation and Operations Program (O.R.A.), implemented by the Municipality of Madrid in November 1980, which seeks to improve the energy efficiency of its transportation system.

Energy Consumption Split

In 1976 the total energy consumed by the transportation sector was 1,120 million metric tons (Tm) of petroleum products. Table 1 shows the split between different transportation users and different origin-destination locations. Urban transportation uses 24.5% of the total petroleum consumed in the transportation sector. Urban passenger transportation in 1976 was 18.1%, or 2 million Tm.

TABLE 1

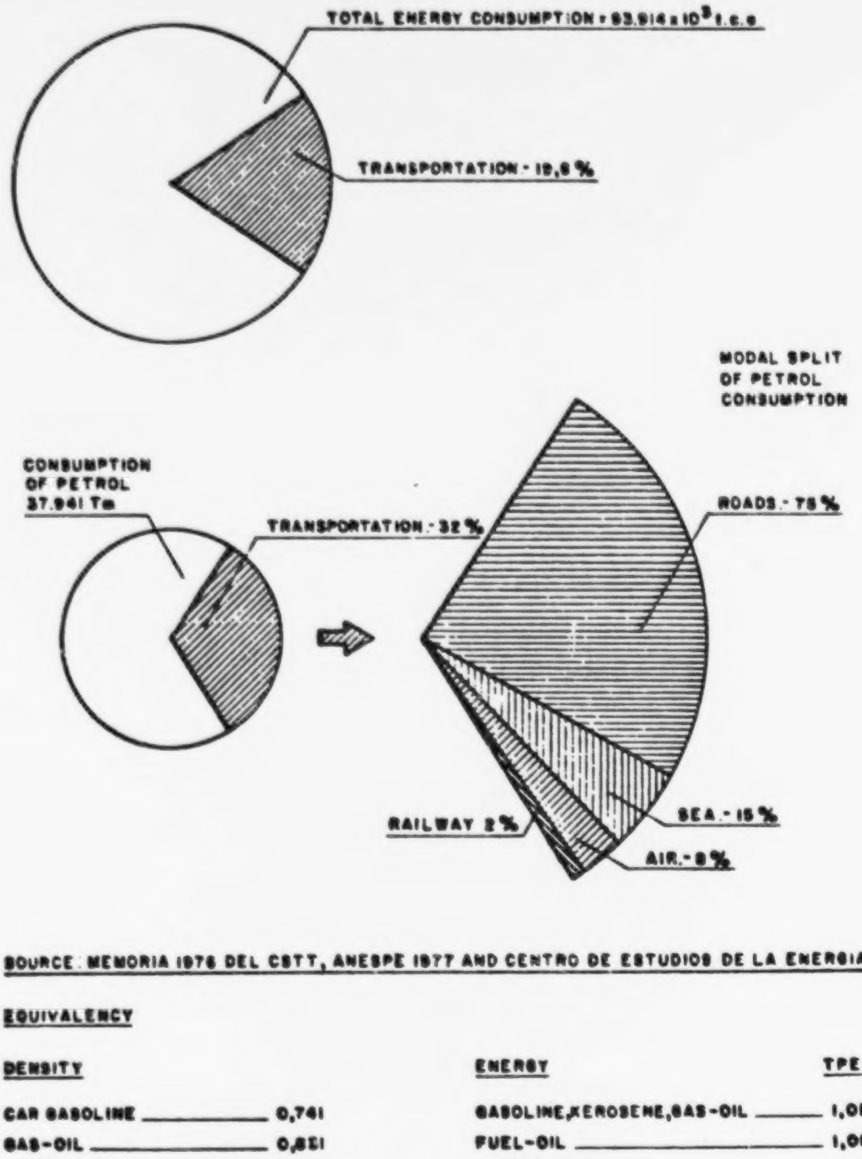
ENERGY CONSUMED BY TRANSPORTATION
(PERCENT OF THE TOTAL IN THE SECTOR)

TRANSPORTATION	GOODS	PASSENGER	TOTAL
Urban	6.4	18.1	24.5
Inter-Urban	22.5	26.2	48.7
TOTAL	28.9	44.3	73.2

SOURCE: Situacion Energetica en la Industria: Sector Transporte.
Centro de Estudios de la Energia.
Ministerio de Industria y Energia.

FIGURE 1

PARTICIPATION OF TRANSPORTATION IN ENERGY CONSUMPTION (1976)



SOURCE: MEMORIA 1976 DEL CSTT, ANESPE 1977 AND CENTRO DE ESTUDIOS DE LA ENERGIA

EQUIVALENCY

DENSITY	
CAR GASOLINE	0,741
GAS-OIL	0,831
AIRCRAFT GASOLINE	0,720
AIRCRAFT KEROSENE	0,787

ENERGY	TPE/Tm
GASOLINE,KEROSENE,GAS-OIL	1,05
FUEL-OIL	1,00
LIQUEFIEDGAS	1,18
Kwh	0,086 Tpe
Tpe	1,428 Tce

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Using only urban passenger trips, Table 2 shows how cars, buses and urban railways split their consumption. Private cars account for more than 80% of total energy consumed in urban passenger transportation. Therefore, private cars are the big petroleum consumers in our cities. Any action taken to reduce private traffic will result in larger benefits than if taken in other transportation modes.

TABLE 2

URBAN PASSENGER TRANSPORTATION - MODAL SPLIT - 1976

Mode	Private Car	Bus	Urban Railway	Total
10^6 pxK	35654	4322	4324	44300
Percent	80.5	9.7	9.8	100.0

SOURCE: Memorias del Consejo Superior de Transportes Terrestres. Renfe.

Modal Energy Efficiency

Table 3 shows energy consumed per kilometer of passenger travel in Spain. These values often overstate the efficiency of mass transportation modes because they fail to consider the actual occupancy levels at which these modes usually operate.

TABLE 3

SPECIFIC ENERGY CONSUMPTION

Mode	(gpe/pk*) Consumption
Car	60-70
Underground	20-30
Suburban	18
Bus	16-20
Motorcycle	25
Moped	10

*Grams of petrol equivalent units per passenger x km.

Table 4 shows consumption per kilometer of passenger travel, based on actual operating conditions.

TABLE 4

AVERAGE PASSENGER ENERGY CONSUMPTION

Mode	Average Consumption per pxk
Car	331
Underground Railway	107
Bus	100(19.2 x 10^{-6} tpe/pk)

The 7-to-1 advantage of buses over cars is reduced to a much more realistic 3-to-1 advantage for Spanish conditions. This is not to suggest that mass transportation is not significantly more energy conservative than the private car. With a 3-to-1 advantage, any measures that shift demand from private cars to buses or railways will reflect enormous petroleum savings.

Strategies for Energy Saving

Both long-term and short-term actions can yield significant energy savings, depending on the restrictions imposed over the transportation sector. In the long range, measures that involve activities in fields other than transportation should tend to diminish the transportation necessity. Land use and economy planning can produce less volumes (goods or passengers) and smaller distances from origin to destination. These measures could yield big energy savings in transportation, but because of their strong inter-relationships with the general activities in any country, these measures must be considered very cautiously, and in any case, need long periods of time to be implemented.

Meanwhile, short-term measures can be taken that will not reduce economic activity. Rationalization in every transportation mode can save energy; technological improvements for better energy efficiency, and operational changes (differentiated fares, more occupancy, speed, etc.) are the main sources of savings without introducing significant changes in the existing situation. Both in the short-term and in the long-term, certain measures can produce savings in energy, including planning and design details in the infrastructure (ramps, curves, etc.).

In order to give an idea of the effects that could result from rationalization, the Spanish Centro de Estudios de la Energia in 1979 made some recommendations which may save between 713 and 1,650 x 10^3 Tm petroleum equivalent. This means a total savings of 6% to 13% of total petroleum consumed in the transportation sector.

However, the most promising field in urban passenger transportation energy saving is the "mode transfer." Measures that force passengers to change to more energy efficient modes do not significantly change the activity in the sector. However, these measures modify the quality of life, positively or negatively depending on citizens' points of view.

The Madrid O.R.A.

The main scope of the O.R.A. operation in Madrid has been to produce a shift from the private car to public transit modes (bus, underground and suburban railways). Travel speed in the CBD of Madrid was very low and congestion disrupted not only the private traffic but bus and taxi traffic. The zone under the O.R.A. control has high accessibility to public transit (bus and underground) and used to be very congested because of the high rate of parking violations (double parking, illegal parking, etc.).

Users are differentiated in two types: residents and non-residents. Non-residents may park for a maximum of 1.5 hours. A price of 15, 30 or 45 pesetas is imposed on vehicles parking 30, 60 or 90 minutes, respectively. Payment is controlled through a card system showing month, day and time of arrival at the parking place. Residents are allowed to park their cars with no time limitation but only in the same subzone as their residence. The annual payment for this permit is 900 pesetas, which is merely symbolic.

The two main objectives of this measure are:

1. drastically cut private car trips that include long parking periods (usually work trips), and

2. give residents the opportunity to leave their cars near their homes and use mass transit modes.

Both objectives have been achieved to a significant degree. Higher travel speeds, lower traffic volumes and increased number of passengers in buses and underground have been registered.

Analyses are now being made to evaluate changes in travel habits. Energy savings could be evaluated at the same time. These analyses were presented at the Symposium, and the main results are reflected in Table 5.

TABLE 5

DATA ABOUT MADRID O.R.A.

Number of curb legal parking spaces = 18.800
Estimated decrease in veh. x km. = 160.000 (daily)
Average speed increase Centre = 12.5%
Average speed increase Total = 5%
Daily Bus increase in passengers = 32.500
Daily Underground increase in passengers = 30.000 (estimated)

ENERGY CONSERVATION IN THE TRANSPORT SECTOR: THE EUROPEAN EXPERIENCE

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Introduction

Energy conservation in the transport sector has been the focus of several intergovernmental European organizations. These organizations have tried to inform and warn their member countries of the consequences and the advisable measures in this field. One can cite the Economic Commission for Europe (ECE) of the United Nations (UN) whose Inland Transport Committee (ITC) has coordinated efforts and produced a number of documents on the subject in the past five years; the European Conference of Ministers of Transport (ECMT), which encompasses nineteen Western European countries, including Yugoslavia and Finland, has produced one report on the subject and another to be submitted to the Council of Ministers in May, 1981; and the OECD and the International Energy Agency (IEA) have also dealt with the subject as part of the overall energy reporting in their member states. Finally, the European Economic Community (EEC) also has produced some reports and taken steps toward coordination of efforts in the transport and energy field.

This paper analyzes the existing data and provides an overall view of the situation and trends in energy and transport in Western Europe. It is based on reports by the above mentioned international organizations and on replies to a special questionnaire issued by the author to the appropriate energy authorities of some twenty European countries.

The Energy Crisis and the Western European Economies

The energy crisis has affected all Western European economies, but not to the same degree and not with the same magnitude in all sectors of the economy. Some considerable differences exist among the GDPs, rates of growth, and various economic indicators of the various European countries. The most striking of these differences concerns their total energy sufficiency, that is, the ratio of the total energy production over total energy demand. The average self-sufficiency was 33% in 1973, 48% in 1978 and is expected to be 55% in 1985. However, self-sufficiency for 1978 varied from 3-16% for countries such as Denmark, Belgium, Ireland, Italy and Luxembourg, to 20-45% for Austria, Federal Republic of Germany, Spain, Greece, Sweden, Switzerland, to 80% for the United Kingdom, and 200% for Norway. These differences, coupled with the differences in economic growth, obviously have a marked effect on the energy conservation policies adopted.

Following the first real energy crisis of 1973 and its recurrence in 1978-79, a distinct policy goal of all European governments has been to develop their own energy resources as much as possible and reduce their dependence on imported energy. Success in this "front" is also uneven.

For example, the United Kingdom and Norway are now the main Western European oil producers with more than 75% of the oil produced in Western Europe.[1] The United Kingdom and the Netherlands produce more than 75% of the natural gas, while the Federal Republic of Germany produces nearly all the lignite in the Common Market countries and more than 80% in Western Europe as a whole. Similarly, the United Kingdom and the Federal Republic of Germany produce nearly 90% of the coal in the Common Market.

Europe's slow recovery of a certain independence from its foreign oil suppliers is quite remarkable. However, this recovery is still insufficient to offset the prodigious increases in prices and restore the European balance of trade. Within the last ten years, a clear trend, in which there is a reduction in total primary energy (TPE) per unit (GDP), has been detected. The same trend is observed in the percentage of net oil imports to the whole TPE for most European countries. On the contrary, North American countries show an overall trend to increase their percentage of net oil imports to the TPE.

The Transport Share of Energy Consumption

We have considered some of the overall economic and energy trends in European economies. This section concentrates on the transport sector's share of energy consumption by relating the percentage of energy consumption in the transport, industrial, residential/commercial sectors, to the Total Final Consumption (TFC) of energy in each country. The share of oil in the total transport energy consumption for every country is not of special importance because for every country there is almost a total dependence on oil in the transport sector, as shown in Table 1.

TABLE 1

OIL PERCENTAGE OF TOTAL ENERGY CONSUMED IN THE TRANSPORT SECTOR

	1973	1977	1978	1979	1985*	1990*
Europe	97.11	97.62	97.93	97.96	98.10	97.57
North America	99.86	99.91	99.84	99.85	99.90	99.90

*IEA 1979 Estimate

As Table 1 shows, of the total energy consumed in the transport sector, there is an average dependency of 97.5% on oil for European countries and 99.9% for North American countries. European countries appear less dependent on oil for their transport than the North American countries because electric railways form a considerable part of the network in Europe. The share of the transport sector in the Total Final Consumption (TFC) of energy presents a different picture. The relevant data are given per country in Table 2.

European countries show an average share of the transport sector in the TFC of 19% for 1973 and 22% for 1978. For the nine countries of the EEC only, this percentage is 17% for 1973 and 19% for 1978. These percentages are considerably lower than those observed in the United States as shown in the last row of Table 2. In general, this difference between the United States and Europe may be attributed to the higher usage of private cars and road transport in the States. If one considers only oil consumption, a more disturbing trend emerges. The transport sector's share in total oil consumption has been increasing much more rapidly in Europe than in the United States. In 1974 it was 24.5%, while in 1978 it was 32%. The corresponding figures for North America were approximately 42% to 44%.

Within the field of transportation, by far the most energy consuming sector is road transport with nearly two-thirds of its consumption attributable to petrol driven cars and the rest mainly to buses and diesel lorries followed by diesel-engine cars, farm vehicles, and two-wheelers.[4] For example, road transport consumed 89% of the total energy consumed in the transport sector in France in 1973,[5] and 72% in 1979.[6] This figure was 78% for the United Kingdom in 1977[7] and 78% for Greece in 1975.[8]

Energy Conservation Measures and Policies

The various measures taken by Western European governments to conserve and rationalize the energy resources in the transport sector can be examined under the following main headings:

- Transport Policy,
- Restraints,
- Incentives (prices and taxation),
- Research and Development, and
- Public Information and Education.

Transport Policy

Following the first oil crisis of 1973, European governments reacted in different ways according to their national economic objectives and policies. The first step towards a common approach to the energy crisis, including consideration of the transport sector, was the formation in 1974, within the framework of the OECD, of the International Energy Agency (IEA). IEA has twenty member countries, fourteen of which are European. In October 1977,

TABLE 2

ENERGY CONSUMED IN TRANSPORT, INDUSTRY, AND OTHER SECTORS AS A PERCENTAGE OF THE TOTAL FINAL CONSUMPTION OF ENERGY PER COUNTRY

COUNTRY	1973			1978			1985**		
	Transp.	Ind.	Other*	Transp.	Ind.	Other*	Transp.	Ind.	Other*
Austria	20.5	48.3	31.2	23.5	38.8	37.7	21.4	38.0	40.6
Belgium	13.6	51.2	35.2	14.9	48.6	36.5	15.9	50.8	33.3
Denmark	22.0	25.8	52.2	21.4	21.9	56.7	24.3	25.4	50.3
France	17.0	----	----	20.0	----	----	----	----	----
F.R. Germany	16.2	45.2	38.6	18.6	41.4	40.0	16.3	43.3	40.4
Greece	30.7	42.0	27.3	33.0	41.5	25.5	27.8	44.4	27.8
Ireland	25.5	29.4	45.1	28.8	30.5	40.7	27.6	39.4	33.0
Italy	19.4	48.8	31.8	22.1	44.9	33.0	20.7	46.4	32.9
Luxembourg	7.1	78.7	14.2	11.6	70.0	18.4	11.4	70.4	18.2
Netherlands	15.1	43.9	41.0	15.6	41.7	42.7	15.1	47.1	37.8
Norway	18.1	47.1	37.8	28.8	39.6	39.6	20.7	39.4	39.9
Spain	26.0	56.7	17.3	28.4	52.0	19.6	29.7	53.1	17.2
Sweden	14.4	46.4	39.2	17.9	40.6	41.5	17.1	49.0	33.9
Switzerland	24.7	27.6	47.7	24.8	24.2	51.0	26.6	27.2	46.2
United Kingdom	20.0	45.2	34.8	21.8	41.6	36.6	22.2	44.3	33.5
United States	31.1	35.8	33.1	34.3	32.2	33.5	31.5	39.2	29.3

* Mainly residential/commercial.
** IEA 1979 review estimate.
Source: IEA 1979 review, and Reference 3 (France).

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the IEA ministers adopted twelve principles of Energy Policy, including the "strong reinforcement of energy conservation on a high priority basis."

In March 1976, the EEC Council of Ministers approved five recommendations to member states for energy conservation. Two related to transportation are:

1. the improvement of driving habits of drivers, and
2. publicity on the advantages of mass transit.

Since then, little has been done through approved EEC legislation, however, work is continuing within the community mainly on a council directive regarding the approximation of the laws of the member states relating to the fuel consumption of motor vehicles and the influence of taxation on car fuel consumption. Furthermore, studies are underway on alternative fuels and types of vehicles, as well as on energy conservation measures in the transport sector in general.

The energy crisis and its relation to transportation policy of European countries has also concerned the European Conference of Ministers of Transport (ECMT), an organization with 19 European member countries that deals exclusively with transportation problems and policies within Western Europe. A special report on Energy Conservation in the Transport Sector was submitted to the Council of Ministers of the ECMT in November 1979, and further consideration will be given in coming meetings of the ECMT, possibly leading to the adoption of a resolution. This report[1] contains an excellent overview of policies and measures considered or adopted by European governments in the field of transport.

European countries, therefore, have started a process of cooperation in the field of energy conservation in the transport sector, but they are far from setting a common policy in this field. However, common elements do exist and these can be summarized in the following sections.

Promotion of Public Transport Services

This policy existed before the energy crisis primarily on economic objectives, but the need to conserve energy has given it a fresh impulse. However, the energy conservation aspect of public transport usage needs to be publicized adequately so that the public considers it in its modal choice decisions.

Promotion of Rail Services

Encouragement of use of railway services has new impetus both in urban and inter-city transport for passenger or freight. The investments made for new Metro lines in urban areas and better inter-city rail transport services are being reconsidered in most European countries in the light of this new policy. Metro construction had eased considerably ten years ago, but recently more underground lines are being constructed in conurbations of over one million. This is true for France (Paris, Lyon, Marseilles, Lille), Belgium, Spain, and Greece (Athens). Inter-city railway lines are being modernized for higher speeds and comfort (in Belgium, United Kingdom, France), more regular services between large cities (the Federal Republic of Germany and the United Kingdom) and to encourage travel in the off-peak hours (the fare reductions for off-peak hours in Finland and Sweden since 1979).

Leveling off of Road Investment

Several European countries are leveling off, if not reducing, their road investments in favor of other types of transport infrastructure, namely railways, combined transport, etc. Simultaneously, some forms of road investment, notably on cycle-ways among the main roads or in towns, are now re-emerging (in France and the Federal Republic of Germany) to encourage use of cycling. It is worth mentioning that some European countries (the Netherlands, Denmark) never ceased encouraging the use of cycling. The most prevalent characteristic in the investment programs of European countries today is a clear tendency to invest more substantially in public transport (railways, and urban-suburban, and inter-city systems) at the expense of roads and motorways. On the two ends of the scale, according to a recent ECMT questionnaire, only two European countries (the Netherlands and Switzerland) see no reason to modify their policy in this area, as they are satisfied with the qualitative development of their public transport networks as it stands. Spain is the only country to report that the re-orientation of its investment program will bring the construction of new motorways to a halt.

Restraints

"Restraints" mean direct restrictions on:

- the use of the vehicles,
- the use of the fuel,
- the type of vehicles used, and
- the way vehicles are used.

Restrictions in the use of vehicles have been implemented only in two European countries. They comprise traffic bans on certain days of the week. In Greece, vehicles are not allowed to circulate on alternating weekends (i.e., a total of four days a month). In Yugoslavia, more drastic measures were introduced in 1979. Under these measures, unscheduled passenger transport services for distances exceeding 200 kms were banned, and transport for own-account-goods was limited to 100 kms from the place where the vehicle was registered. In addition, cars were not allowed to circulate for a total of four days a month. Other European countries, such as France and Switzerland, ban lorry traffic on Sundays, but this measure was not taken on energy conservation grounds only.

Restrictions in the use of fuel through fuel rationing have not been enforced in any European country, although several of them have made contingency plans for such measures. Plans to close petrol pumps once a week were envisioned for Luxembourg, while Greece has restricted operating hours of petrol pumps since 1979. Pumps must close between 7:00 p.m. to 6:00 a.m. (except for emergencies) on a rotating basis. Measures to restrict the circulation of less energy efficient vehicles have not been applied in European countries other than those caused by the standard periodical mechanical tests for all vehicles.

The way in which vehicles are used has been addressed mainly by introducing and enforcing lower speed limits. Such limits exist in all European countries. A concise picture of the situation concerning speed limits in European countries is given in Table 3. For lorries speed limits are usually lower. All European countries have adopted strong penalties and make serious efforts to enforce speed limits as a result of the energy crisis.

Incentives (Prices, Taxes, Contractual Agreements)

For the most part, incentives to improve energy performance in the transport sector have focused on pricing and taxing policies. Gasoline prices have been raised in most European countries to reflect world market prices while taxes have been increased on fuel and on the purchase of cars. In addition, all European countries apply a system of road taxes, but with differing objectives and structures. Below is a summary of current practices.

Taxes - Prices

In all European countries a road tax is levied for a fixed period of time on the possession or ownership of private cars. The criterion varies as follows:

Criterion	Countries
• cylinder capacity	• Federal Republic of Germany, Luxembourg, Portugal, Switzerland
• fiscal horse power rating	• Belgium, France, Ireland, Italy, Greece
• unladen weight	• Denmark, Netherlands, Finland, Sweden, Turkey
• fixed rate	• United Kingdom, Norway

Taxes on cars relating directly to fuel consumption generally have not been introduced, although France relates taxes to fuel consumption on vehicles registered after 1977. Austria and the United Kingdom are considering similar reforms. Taxes on the purchase of a car can be used as a negative incentive to slow down the growing number of cars. In Greece, for example,

TABLE 3

SPEED LIMITS FOR CARS IN EUROPE (KMS/HR)

COUNTRIES	Before the November 1973 Crisis		During the 1973-1974 Crisis		Situation as of September 1978			
	Ordinary Roads	Motorways	Ordinary Roads	Motorways	Ordinary Roads	Motorways	Ordinary Roads	Motorways
Austria	unrestricted	unrestricted	100	100	100	130	100	130
Belgium	90	unrestricted	80	100	90	120	90	120
Denmark	unrestricted	unrestricted	80	80	90	110	80	100
Finland	----	----	---	---	80 to 100	100 to 120	80 to 100	100 to 120
France	100 (110 or 120)	unrestricted	90	120	90	130	90	130
Germany	100	unrestricted	80	100	100	130 (advisory)	100	130 (advisory)
Greece	110	unrestricted	80	80	80	100	80	100
Ireland	95	----	80	---	95	---	95*	---
Italy	unrestricted	unrestricted	100	120	80 to 110	90 to 140	80 to 110	90 to 140
Luxembourg	90 (110)	unrestricted	80 (100)	100	90**	120**	90**	120**
Netherlands	unrestricted	unrestricted	80	100	80	100	80	100
Portugal	unrestricted	unrestricted	80	100	90	120	90	120
Spain	unrestricted	unrestricted	90 (advisory)	90 (advisory)	90	100	90	120
Sweden	70 to 90	110	70 to 90	110	70	115	70	115
Switzerland	100	unrestricted	100	100	100	130	100	130
Turkey	---	---	----	---	---	---	90	90
United Kingdom	112	112	80	80	95	110	95	110
Yugoslavia	unrestricted	---	unrestricted	---	80 to 100	---	80 to 100	---

Notes:
* Lower limits have been introduced in certain cases.
** Maximum authorised speed depends on engine capacity.
In Norway, the proportion of main roads on which speeds are limited to 70 or 50 kph has increased from 15% to 25%.

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taxation generally increases the normal price of a car to almost three times its imported, pretax value. Since the introduction of these high taxes in 1978, the purchases of new cars, especially those with high cylinder capacity, have dropped drastically. Taxation also has been used by European governments to influence the choice of more efficient fuels or cars. As a general rule, diesel fuel is less heavily taxed than premium grade petrol, and the tendency has been to increase the difference between the two since the energy crisis. In Italy taxes on diesel fuel were reduced while those on petrol were increased considerably between 1973 and 1977. As a result, the average car mileage fell by about 25% in the country. In Ireland indirect taxation on diesel fuel has not changed since 1969, while that on petrol has doubled over the same time period. Other European countries also are considering measures of further tax differentiation between petrol and diesel fuels. Some European governments have used tax rebates to public transport operators to improve their services and induce more ridership. In France the VAT on public transport was reduced in 1974, whereas in Finland the fuel tax has been partly refunded to road public transport operators since 1978. In both cases the loss of revenue was made up by increases in taxation on the other road users. The Federal Republic of Germany is considering tax rebates to car owners who use public transport for their journey to work trips.

Fuel pricing has also been used as a means of influencing fuel consumption. In the United Kingdom, fuel prices were raised by 50% in the course of 1979, a measure which should curtail consumption. In France the aim of government policy is to pass on to consumers the entire increase in costs borne by producers. Even so, in francs, at constant prices, petrol is still 28% cheaper than it was in 1957.

Contractual Agreements

Many European governments have used special contractual agreements with various organizations to address energy conservation:

- In Spain energy conservation agreements have been made with various branches of industry, but not yet with the transport sector.

- In Sweden an energy conservation agreement has been signed between the National Committee for Energy Conservation and the Road Haulers Association. This agreement recommends certain rules on routes and driving behaviour.

- In France the Agence pour les Economies d'Energie has made agreements with the SNCF, RATP, and Road Haulers. The objective is to reduce consumption per passenger-km or tonne-km in 1985 by 10% for road transport. This is not to be achieved by a lower level of activity but by better productivity. Productivity would no longer be calculated per manshift, but by fuel consumption. These agreements bring to light a new concept of productivity that should be included in the calculations of chief executives in the same way as other data.

- The Federal Republic of Germany is taking the same approach. Car manufacturers have undertaken to lower the specific fuel consumption of cars by 10-12% and that of commercial vehicles by 5% by 1985. They are even prepared to revise these figures in order to obtain better results in a shorter period.

Research and Development

In Europe, the main efforts in this field are directed towards the construction of more energy-efficient vehicles and towards the development of alternative fuels.

Energy Efficient Vehicles

In several European countries, the motor industry has pledged itself, generally on a voluntary basis, to reduce average fuel consumption in new vehicles:

- In France the 1985 target for new vehicles is 7.3 litres per 100 kilometres, and for 1990, six litres per 100 kilometres. Pending the gradual replacement of all cars now in use, a reduction in existing consumption is already possible by installing special fittings (consumption indicators, standard engine settings, aerodynamic deflectors). The fittings are expected to be installed at a rate of two million private cars and 600,000 lorries a year.

- In Germany, as already stated, motor manufacturers have undertaken to reduce cars' fuel consumption by 10-12% by 1985 and that of commercial vehicles by 5%.

- In the United Kingdom the motor industry has pledged voluntarily to reduce the average consumption of new vehicles by 10% over the period 1979-1985.

- The Swedish Government is currently negotiating with motor manufacturers to reduce the consumption of new vehicles by an average of 10% in the short term with a more ambitious aim for 1990.

Alternative Fuels

Using forms of energy other than oil would be, of course, the most radical solution. Four main substitutes are considered: alcohol, synthetic fuels, hydrogen, and electric power. Although the scope for substitution is fairly limited, several European countries are financing research and development programs in this area. In addition, several experiments are under way to introduce a new type of bus: "hybrid" or "bi-modal" vehicles. Since 1979, twenty hybrid buses have been in service in Stuttgart and Wesel. The diesel consumption of these buses is 10% less than that of comparable vehicles of traditional design. In 1979, five bi-modal buses entered service experimentally for the same purpose in Esslingen.

In Denmark studies are being carried out on the development of hybrid buses, while certain Belgian inter-communal transport companies also plan to introduce bi-modal buses in the near future. Finally, we should mention the work in the European Community (the Technical Committee on "New Modes of Transport"), the UIC and the UITP.

Public Information and Education

Education of drivers on energy conservation has been recognized in Europe to be an important step in the effort to conserve energy in the transport sector. Driver training is usually a once-in-a-lifetime requirement, that is, to obtain a license. Certain countries, like France, already include energy conservation in driver training courses. Such measures are very cost-effective. If more economical driving can be achieved, fuel consumption can be cut by 15-20%. Of course, a prerequisite is that the driving instructors are fully trained themselves.

In addition, public education has been used widely as a way of developing awareness of the advantages of economical driving and rational decisionmaking when choosing a car. Different methods have been used by European countries during the past few months to develop public awareness. These measures have been divided into three categories:

1. Action to influence the consumer when he makes his choice of car by requiring the motor industry to publish objective consumption figures.

2. Advertising, either of a general nature or stressing particular aspects, by press, radio, television, and poster campaigns.

3. Issuance of brochures or pamphlets advising the motorist how to drive economically.

Virtually all European countries are campaigning to develop public awareness, and half of them have adopted (or plan to adopt) the idea or are requiring the motor industry to publish objective and standardized consumption figures, as well as encouraging more economical driving.

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TRANSPORT SYSTEM'S OIL DEPENDENCY: A LONG-TERM SYSTEM DYNAMICS POLICY ANALYSIS

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New Transportation and Energy Model Indicates: "Action Should Be Taken Now to Prepare For Future Oil Crisis"

At the Institute of Transport Economics in Oslo, we are working on a new transportation computer model. The model deals with important parts of passenger transport and communication. The model indicates that certain measures can reduce substantially the transport systems vulnerability to increasing oil prices on the world market. However, new policies must be introduced at the earliest possible time. We cannot wait to see how the oil market develops. The long-term effects of measures taken depend very little on the oil price development in the short-term.

The investigations use two extreme alternatives for the price development of crude oil products. These alternatives are combined with different oil production rates on the Norwegian continental shelf.

Sharp increases in both oil prices and oil production will increase our economic activities and thereby the travel and communication level of the country. Increased gasoline expenses will reduce slightly the growth rate of transportation.

Currently, only four transportation sectors are included in the model: passenger car, bus, pedestrian/bicycle, and telecommunication-sector. Several other sectors should also be included, such as railway, coastal transport, air transport, and mail. Ten different policies are tested in the model. Several hundred combinations of these measures are also investigated. Other policies should be tested later on by new model runs if the model is expanded beyond the four transportation sectors now included.

The transport system's vulnerability under future oil crises is used as a performance indicator of the policies. Actually, the inverse notion is used. This so called "preparedness" or "robustness" is defined as the relation between two properties --

1. Annual totals of national travel and communications
2. Annual fuel consumption by motorized transport.

The measures investigated also influence the level of economic activity of the country. This performance indicator is measured by the Gross National Product (GNP).

Model Analyses Give New Knowledge About the Effect of Policies

For many years, data collection has been extensive in many special areas of the transportation field. Norway has made a major effort in the past 20 years to increase its level of information. But, it is very difficult to get a good view of the dynamics among different areas, that is the interrelationships between and within transport sectors and between transportation and other community activities. Simultaneously, we are influenced by changes in the world economy and by measures taken outside the transportation sector in our own country.

This model project attempts to analyze the combined effect of different policies in several areas. Although the level of knowledge today is relatively high, many of the problems are so complex that we still lack knowledge in many areas. Consequently, to include all factors we consider important for the problem, parts of the model also have to be based on judgment and experience.

In order to clarify details, we think an assessment of the total problem is more important than an investigation of single factors. Studies of parts of problems cannot give answers to the aggregated questions within transportation. We think that it is better to make assumptions and use judgment if the alternative is to overlook one factor. Afterwards, we may carry out sensitivity analyses to determine the need for accurate quantification of the uncertain factors.

Measures Can Give the Transportation System Protection During Future Oil Crises

By the end of the century, the transportation system's vulnerability may be reduced to half by combining several measures. However, this significant result requires that the measures be taken immediately. The effect of the measures are nearly independent of the rate of increase of oil prices. We need not wait to see how the oil market develops before we take action.

Combination of several measures can have a stronger effect than the sum of the effects of the single policies. But combinations of policies may also reduce each other's effect, due to unfavorable side effects of the policies which are reduced or increased by other policies. This applies to both the effects of oil crises on transportation and to the economic activity of the country. The best combination of four policies relating to Norwegian conditions are:

- Model Measure No. 2: Increased gasoline prices,
- Model Measure No. 3: Reduced gasoline consumption in new cars,
- Model Measure No. 4: Increased supply of telecommunication services,
- Model Measure No. 6: Reduction of road capacity development.

We call this combination of policies a typical "give and take" combination, where all the policies are saving energy. Policy No. 2 and 6 reduce the traffic and thereby the energy consumption in combination with the reduction of car operation costs. Policy No. 4 may give alternative means for those who suffer from bad road conditions. The improved telecommunication service will thereby also save fuel for the transportation.

Two commonly suggested bus policies have little effect on the fuel consumption of the transportation system. Those bus policies are the reduction of fares (Model Measure No. 8) and improved passenger comfort (Model Measure No. 9). However, these two policies can increase bus ridership somewhat.

Measures in One Sector Also Influence Other Sectors

Policies introduced in one sector usually also effect other sectors:

- Increased number of passengers in private cars reduces transportation costs. This increases the total demand for transportation which, in the long run, also increases bus traffic. We get similar effects from reducing gasoline consumption in new cars.
- Increased gasoline prices reduce private car traffic as a short-term effect. But this effect is reduced over time, as we buy more economical vehicles. Consequently, gasoline prices will play a less important role in the long run.
- Supply of better and more telecommunication service will increase total demand for communication and transport. The demand for passenger transport thereby is reduced only slightly by the new telecommunication service. Private car transportation especially will remain high. Bus and pedestrian/bicycle traffic will lose most in the competition.
- Similarly the pedestrian/bicycle improvement policies will cause substitution of traffic, especially from the bus and telecommunication sector.
- When less road capacity is constructed in areas with traffic congestion, the energy consumption of the private car sector will be

strongly reduced. However, the vulnerability of the total communication system under future oil crises will not be reduced to the same extent.

- Reserving lanes for the bus sector and otherwise giving priority to buses remarkably increases bus passenger traffic. Furthermore, this measure has approximately the same effect as the reduction of road capacity.
- Rationing of fuel for the private car sector will increase the bus passenger traffic in the same manner as the reserving of lanes for the bus sector. By rationing gasoline we may, of course, save approximately as much fuel as wanted. But this measure also reduces the growth rate of economic activity in the country.

Principles Behind the Computer Model

The interaction between the different transportation sectors and between transportation and the rest of the community is very complex. No single person may hope to get the total view of this complex set of cause-effect relationships without over simplifying. Though our model contains several hundred concepts, it too has included some simplifications. To suggest how the model works and how it can be used, we shall discuss some of these concepts.

To simplify the description, Figure 1 aggregates information and passengers under the classification of "Transportation." In this way transportation in the figure is the requisite to perform communication among people and between people and nature or machines.

Realized transport is central in the model and is found in the middle of the figure. The right hand side of the figure represents the supply part of the transportation sectors. The left hand side represents the demand parts of the model. This represents the economic activity that creates demand for transport.

The arrows in the figure express the influence between factors. The direction of an arrow shows the direction of the influence. Beside the point of an arrow, we have a plus or a minus. The plus sign indicates that the factors in the beginning and end of the arrow are changing in the same "direction." This assumes that all other factors are unchanged. For example, as economic activity increases, we think that the latent demand for communication also will increase. Note that "communication" is used here in the very broad sense of all personal travel and the transfer of all information.

If all the signs in a causal loop are positive, then we have a positive feedback loop. Such feedback will amplify changes. The amplification may work two ways. It can amplify an increase or a reduction tendency. If the level of realized transport is reduced, this may have a restraining

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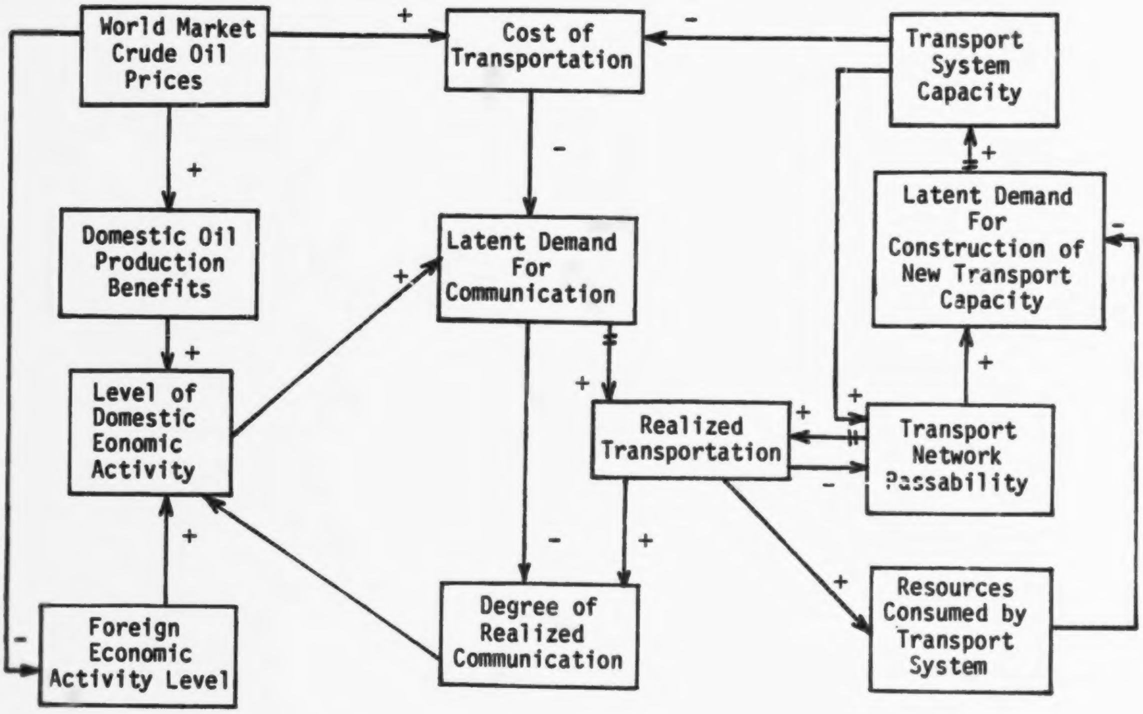
FIGURE I


World Market Crude Oil Prices
Cost of Transportation
Transport System Capacity
Domestic Oil Production Benefits
Latent Demand For Communication
Latent Demand For Construction of New Transport Capacity
Level of Domestic Eonomic Activity
Realized Transportation
Transport Network Passability
Foreign Economic Activity Level
Degree of Realized Communication
Resources Consumed by Transport System
+
-
+
-
+
+
+
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-
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The figure shows how changes in the economic activities in the country will influence realized transport and the demand for new transportation capacity. This in turn will have feedback effects on the economic activity level of the community. In real life we have a network of such feedback forces.

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influence on the level of economic activity in the country. This in turn will reduce the level of latent communication demands. After some time, this will give further reductions in the realized transportation.

Two dashes across an arrow in the figure mean that this effect will be more delayed than for other causal relations. Such delays are very important for understanding the development within transportation and in the community. Not all causal relations are realized in the short-term. Many include a significant time dimension which too often is overlooked or understated. The danger is that we may try to explain these changes by more recent events which can give wrong answers and create great confusion.

If a loop in causal relations contains an uneven number of minus signs, we have a negative feedback. That means, for example, if the economic activity in the country increases, it will, as mentioned, give an increase in the latent communication demand. But this again will immediately reduce the degree of communication realized. Furthermore, this will reduce growth in economic activity as mentioned earlier. If a factor in a negative feedback loop changes, the causal effects will try to bring it back to its original level. The negative feedback works like an automatic temperature regulator.

The Development of Demand for Communication is Influenced by External Forces

Due to Norway's large foreign trade, the increase in economic activity in the country is determined to a large extent by the economic growth in the rest of the world. Consequently, an increase in economic activities in the world will increase demand for Norwegian products and services, which in turn will increase domestic activities. For example, we have the new and very interesting Norwegian oil resources. Increased oil prices and oil production may increase our domestic economic activities. On the other side, the increase in crude oil prices will reduce the economic activity in the rest of the world and also increase the domestic transportation costs. These factors may reduce the economic growth in our country.

The Transportation Section Has Its Own Internal Driving Forces

An increase in the realized transport will reduce passability. That indicates increasing demand for development of new road capacity. After some time, this may increase growth in the construction of road capacity. New roads are constructed usually to state-of-the-art standards which allow higher traffic speed, shorter travel time, reduced travel time, and thereby reduced transportation costs. This, again, will stimulate the latent demand for communication. Finally, we will have a new increase in the realized transport.

We also have several negative causal loops in the transportation sector, two of which try to maintain a constant passability level. One is the loop through realized transport and the other through a transport capacity.

In the future, development probably will be influenced strongly by environmental and resource consumption factors. These factors will try to reduce the growth in transport capacity and such an effect will be stronger as the resource consumption in transport increases. Therefore, in the future, the effect will be more important but already we clearly have felt this increasing power.

The four transport sectors which are built into the model are represented by four fairly equal model parts. Each part is in principle a copy of the right hand side of the figure. The four transport sectors of the model are combined by adding each respective traffic volume to one grand total "realized transport" volume.

The Interaction Between Transport Sectors Is Important For Traffic Development

Transport volume in one sector may increase at the expense of other sectors. The growth of transport in one sector, therefore, may be much larger than the general increase in transportation. That is probably one of the main reasons for the fast growth in private car traffic in the 1960s in Norway. For example, better conditions for car traffic made it more possible to live further away from place of work and services. The traveling distance thereby increased beyond the walking and the bicycle possibilities. Thus, we had extra growth in car traffic, which increased demand for road capacity.

The Need for Future Research

The future developments among factors internal to a system affect each other mutually. Also, this simple model of the real world will give a complicated development picture for the different factors involved. We have programmed the model for simulation of development over time. The results of the computations may show to what extent the hypothesis of causal interactions built into the model can reproduce the historical development for each factor.

Sensitivity analyses may indicate the need for future research in different fields. Typical examples are:

- increased or reduced rates of growth in economic activity caused by changes in traffic and communication realized;
- similar effect on latent demand for communication from economic growth and crude oil prices;
- the degree to which environmental and conservationist pressure groups restrict new road capacity;
- the effect of change in traffic volume and transport capacity on passability and vice versa; and
- delay of causal effects, such as those marked by double dashes across arrows in Figure 1.

SWEDISH EXPERIENCE IN POOLECTIVE TRANSPORT

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Abstract

This paper describes Swedish experiences in vanpool and carpool projects ("poolective transport") from 1978 to 1981. Campaigns to promote carpooling at workplaces have failed primarily because the Swedish tax system provides no inducement for commuters to engage in carpooling.

A commuter vanpool project successfully serves a railway station in a rural area. During the first stage of the project (October, 1980 to February, 1981), rides have been free and voluntary drivers have been recruited by an ombudsman. The vanpool averages 15 commuters per day and saves about 1,000 litres (264 U.S. gallons) of petrol per month in a community of 500 people. In the second stage of the project (March-December, 1981) riders must pay, as the bus will be integrated into the Regional Transport Authority.

The experiences from these two projects have initiated two new projects. The first one uses cars and vans equipped with mobile telephones, a personal paging system, hi-fi headsets, etc. The poolers find the service very attractive and the seat occupancy is 70-85%. The second one, scheduled to start in September, 1981, will be directed to commuters who have unsatisfactory public transport service. The driver will be paid on a mileage basis by the Transport Authority, and the passengers will pay by using the monthly passports issued by the Transport Authority and sold by the employer.

The conclusions are that poolective traffic can be stimulated by the price mechanism and by marketing methods. Preferably, it can be seen as a complement to the public transport system.

Introduction

The rising cost of fuel has turned attention in Sweden, as well as elsewhere, to more efficient use of cars, especially in travel to and from work. The average occupancy for such trips now is only 1.25 persons. In 75% of the cases, the driver is the sole occupant. Thus, various forms of carpooling and vanpooling ("poolective transport") are thought to be effective means to conserve energy in the short-term, especially if distances are long and the alternative of public transportation is not available.

The Traffic Planning Department at the Chalmers University of Technology in Goteborg, Sweden has undertaken research, with grants from the Swedish Transport Research Board, to promote more poolective transport. Two demonstration projects are described in this paper. The projects include carpooling campaigns at four workplaces, and a community bus experiment. Four major industrial workplaces were selected for the study, which was undertaken from 1978 through 1980.

Definitions

Paratransit, according to the Paratransit Handbook (1979), applies to "those forms of intra-urban passenger transportation which are available to the public, are distinct from conventional transit (scheduled bus and rail), and can operate over the highway and street system."

Poolective transport is a form of paratransit organized for a specific group of persons, belonging to a certain workplace, community, club, etc., and having the same origin-destination combinations.

Carpooling Experiment at Workplaces

Survey

A survey of people's attitudes showed that the choice between car sharing or driving alone depended mainly on whether one preferred the freedom and convenience of the latter or the economies of pooling. Many solo drivers were noticeably skeptical of the convenience and reliability of carpooling and considered carpooling altogether too troublesome. (See Figure 1.)

High-income employees with variable hours of work perceived less benefit to carpooling than did blue-collar workers with fixed hours and lower incomes. However, with their obvious potential for sharing, white-collar workers appear to be the best group in which to encourage carpooling. We should note that one-third of the solo drivers were in favor of carpooling but could not find others with whom to share. Another third of the solo drivers were undecided, and the rest definitely opposed carpooling.

Experiences

A carpooling management system was organized, but the campaign to promote carpooling stimulated very little interest. Less than 10% of all solo drivers who drive more than 10 kilometres to work made inquiries. Of those who did inquire, most lived so far apart from each other that pooling could seldom be arranged. No noticeable increase in carpooling could be ascribed to the campaign.

TABLE 1

SPECTRUM OF VARIOUS TRANSPORTATION MEANS
(PARATRANSIT IS MARKED BY DOTTED LINES)

User Organizer	Individual(s) (private transport)	Specific group of persons (poolective transport)	All Persons (public transport)
Individual	Private Car	Car Pool	Lift-Giving Hitch-Hiking Black Taxi
Employer (Company)	Company Car	Car Pool Van Pool Bus Pool	-
Institution (School, social Service, etc.)	Official Car	School Transport Social Transport	
Club, Cooperative, Community, etc.	Shared Car (Pool Car)	Van Pool Charter Bus	Community Bus
Taxi Company	(Private) Taxi	Shared Taxi (Taxipool)	Collective Taxi (jitney, dolmus, etc.) Limousine Service
Public Transit Authority or Company	Publicar	Charter Bus	Dial-a-Ride Scheduled Service

NOTE: There will be no difference if the vehicle is owned by the organizer or leased.

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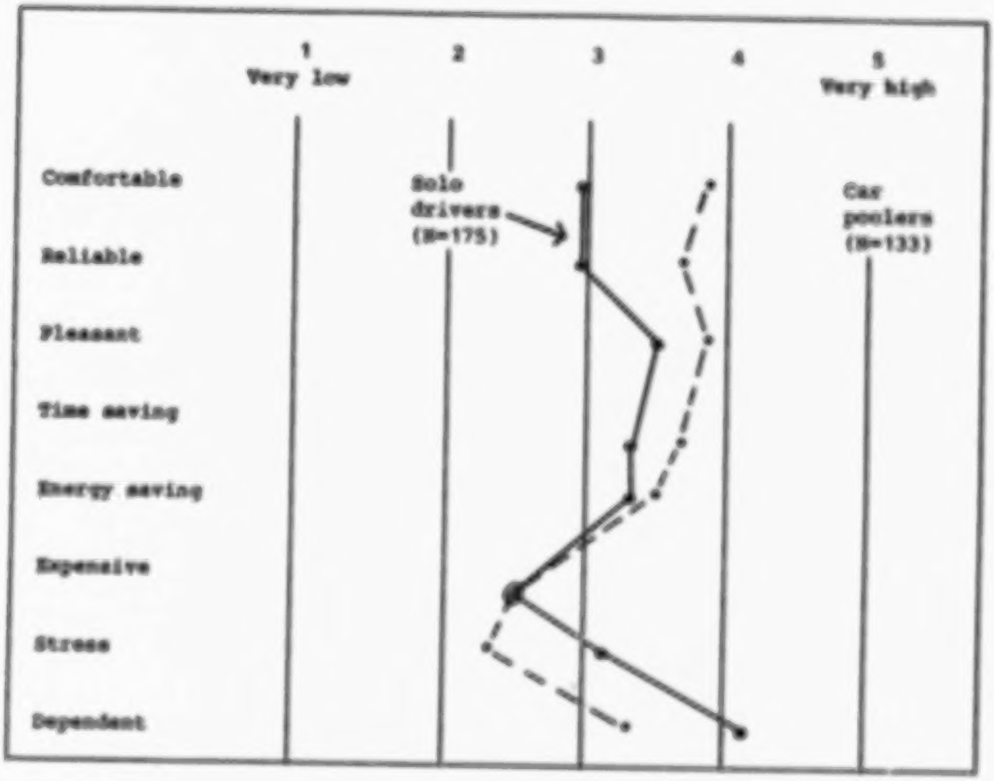
FIGURE 1



Attitudes to various qualities for car pooling. Comparison between solo drivers and non-family car poolers.

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The results of the study suggest that the present Swedish tax system discourages commuters from engaging in carpooling. To take more than one paying passenger is uneconomical due to the tax system. For example, a commuter who regularly drives an automobile to and from the workplace is allowed to make a tax reduction of 7 Sw.Cr. per 10 km (about 22 cents per mile) if the time saving per day in comparison with a transit ride is more than 1.5 hours per day. The tax reduction would be lower for carpoolers. Motivation is reduced further for individuals with high incomes, as the net cost of solo driving is less than 1% of their disposable income.

Other carpooling and vanpooling schemes in Sweden are based on employers. Organized ridesharing is already common, for instance, in the forest products industry where employers provide some 3,000 cars and minibuses for the purpose. Another example is commuting by commuter bus and contractual carsharing arranged by Volvo at its Olofstrom plant, located in a rural area.

Figure 2 compares this plant with a similar industrial plant in the city of Goteborg (SKF plant) and shows that car occupancy is 1.42 persons for the rural Volvo plant and only 1.21 persons for the urban SKF plant. The percentage of solo drivers is 21% and 50%, respectively.

Strategies for Carpooling

As a result of the negative experiences in the carpooling campaign, a number of strategies have been proposed to promote more efficient use of passenger cars. The strategies seek to make the public aware of the need to change community habits. Change is encouraged, and opposition to such change is discouraged. The strategy has four basic points:

1. Activate the price mechanism to regulate consumption in commuter travel.

2. Facilitate the desired change in commuting habits and provide incentives to avoid an unacceptable lowering of travel standards as a result of price alterations and other restraints.

3. Arrange for some equitable division of the costs and responsibilities (for coordinated commuting) between individuals, employers, and the community.

4. Restrict the circulation of private cars in cities, while giving various forms of priority to high-occupancy vehicles.

Put into concrete form, these ideas may be developed as follows:

- Consider commuter travel to be in part private consumption, in part an element of labour as a production factor.

- Allow the employer to take on a greater degree of responsibility for such travel by paying tax-free allowances corresponding, for

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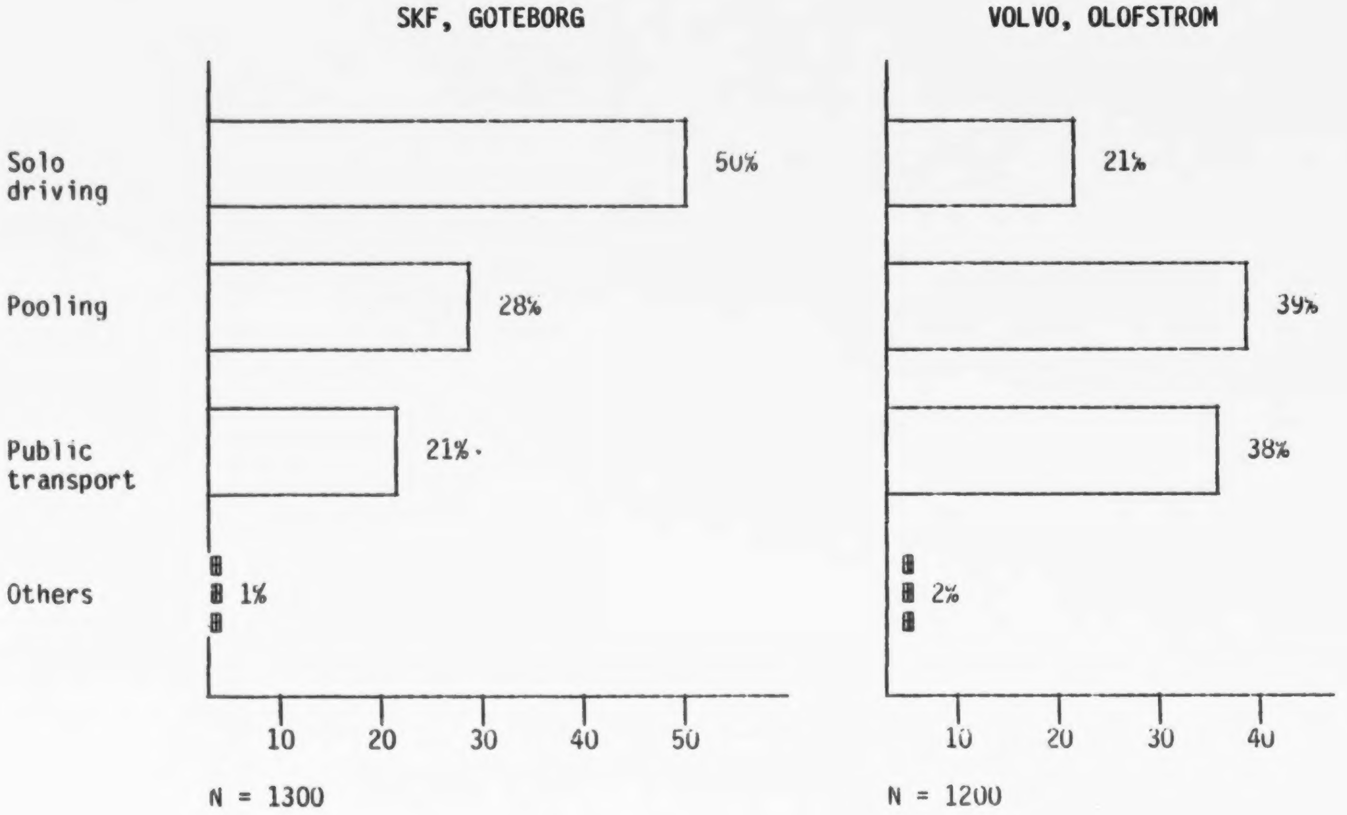
FIGURE 2



Comparison between the modal distribution for commuters at the SKF Plant in Goteborg and the Volvo Plant in Olofstrom.

example, to half of the marginal cost of travel by car or half of the fare for public transportation.

- The individual tax deduction could then be abolished and the resulting additions to government revenue (amounting to 4-5 billion Sw.Cr. per annum) distributed to employers as compensation for their outlay and trouble, and to local authorities for the development of public transportation (including subscription as well as special commuter bus services) and organizing contractual car sharing.

Community Bus Experiment (Byabuss)

Background

This project was initiated in July, 1980 as a platform for community paratransit innovation. The target is to establish gradually a multilevel, area-wide transport capacity for an isolated rural community and to develop guidelines or important system elements that can serve similar communities elsewhere in Sweden. This is a very small, experimental demonstration project aimed at covering a village of 500 people together with its surrounding rural hinterland.

The project is monitored by the County Board and is under the immediate direction of the local community. The first development stage runs from October, 1980 to February, 1981, the second from March, 1981 to December, 1981.

The Community of Ingared

Ingared is a new development area approximately 40 kilometres to the east of Gothenburg in the south of Sweden. This outlying ex-urban community presently consists of 180 houses with 300 anticipated by 1985. Currently the only public transport service available is provided by a suburban rail line offering some 18 connections per day to central Gothenburg from a small (and rather dangerous) stop and an at-grade rail crossing located about two-and-one-half kilometres away.

Incomes in the area are high even by Swedish standards. Over 40% of the households have two cars, and 300 residents have driver's licenses. Furthermore, since it is a new community settled entirely in recent years, the population is basically auto-oriented--in contrast with most rural areas where the population often has been "left over" from an earlier, but no longer operative, system of mobility and access from the modes.

Service

An array of services will be identified, tested and brought on line in stages over the next several years. The "Community Bus" (Swedish: byabuss) is similar to those seen in the United Kingdom or Dutch Buurtbus programs. Beginning on 1 October 1980, this volunteer bus (8 passengers, normal driving license) is parked at a convenient central location from which it functions as a transit feeder. At first, the Byabuss will serve only trips to train times. Average walking time from houses to the central pick-up point is 3 to 4 minutes. Return trips also will be made from the railway station to the central origin point. The service to the trains includes three tours in the morning and five tours in the afternoon. During off-peak hours, the Byabuss will provide services for scouting, churches, and other community activities. In the first stage (October, 1980-February, 1981) free transportation service is provided. The drivers are recruited by an "ombudsman," one for each day (Monday-Friday) and for one of the five streets. During this period, about 50 persons have been active in the cooperative and some of them are not riders, but will serve for the good of the cause. The trip frequency (one way) has been:

Commuters	15 per day
Children	229 per week

Five commuters left their cars at home when the bus service started. The total energy savings has been about 1,000 litres per month.

In the second stage (March, 1981-December, 1981) the users have to pay for the ride. The inhabitants will establish a bus committee which will contract with the Region Transportation Authority. The ticket passport will cost 260 Sw.Cr. per month for regional trips (an increase of 60 Sw.Cr. or $14) and the local fare will be 3 Sw.Cr. for a return trip (children under 7 years will be transported free of charge). Fees will cover about 75% of the cost.

Other Projects

Teletrans

This project has been carried out at the Nordic Institute for Studies in Urban and Regional Planning in Stockholm. The purpose is to test a form of organized ridesharing combining the advantages of public transport with the convenience of the private car.

Pools have been organized at three big plants (in Stockholm, Goteborg and Norrkoping) using vans or cars. The pool participants are all white collar employees. The fee is about $17 per month, equal to the monthly ticket for public transport in Stockholm. (The driver gets free travel.) The vehicles are equipped with mobile telephones, a personal paying system, hi-fi headsets at every seat, etc. To avoid waiting outdoors the passenger is called by a signal from the paging system. The seat occupancy after the first year of operation is 70-85%. Interviews show that increased comfort and private car costs is seen as a major advantage of ridesharing compared with car driving. The project will be finished in October 1981.

GL Carpool Experiment-1981

This carpool project, initiated by the Goteborg Regional Transport Authority (GL), is scheduled to start in September 1981. It illustrates how poolective transport could be integrated in the public transport system. The background is that the tax regulation will change in 1982 with the possibility of allowing a tax reduction for commuting by car. (The time saving should be more than 2 hours per day, and the travel cost of the first $200 could not be reduced for any commuters.)

- Employees in industrial areas outside of the city of Goteborg will be offered the opportunity to form carpools, if the public transport service to and from the workplaces is poor or does not exist. A study shows that one-third of the employees have unsatisfactory public transport service.
- The driver in the carpool will be paid by GL, corresponding to the fuel costs. The driver has to sign an agreement with GL on regular pool service, and agree to make a tax reduction for the vehicle costs.
- The carpool passengers pay by buying regular monthly passports, issued by the GL (about $30-60, depending on the distance). The passport will be sold by the employer.

The arrangement of this carpool is legal according to the Swedish Transportation Act.

Further Steps

The conditions for the 'Byabuss' will be studied further as a tool for serving low-density areas. Other similar projects in the Goteborg Region will be initiated.

The possibilities to use telephone and computer aids also will be studied in the process to find solutions for getting information on the travel demand, recruitment of drivers, paying, etc.

The basic philosophy will be to find simple and easily understood solutions. The new form of social organization, based on a local cooperative, involves a lot of interesting social effects.

This project has shown so far that the cooperative idea can be applied in transportation with great success.

Conclusions

1) Poolective transport in Sweden has the potential to save energy of up to 30% for carbound commuters.

2) The price mechanism must be activated to promote poolective transport by changing the tax system for commuters by cars, reducing costs for parking, providing time saving measures by reserved lanes and parking lots and by increasing the status for car poolers.

3) Poolective transport actions must be directed to specific groups who have poor public transport services.

4) Poolective transport should be seen as a complement to the public transport and if possible be integrated in the public transport system.

5) Poolective transport can be arranged not only from a workplace but also from a neighborhood, a community, etc. Community-based pools can also include the transport of children and recreational trips.

6) Organizing poolective traffic is a marketing matter and not a technical problem.

ENERGY CONSERVATION IN TRANSPORTATION SYSTEMS PERFORMANCE

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Introduction

The degree to which transportation systems are dependent upon energy supply and price is well understood. While transportation accounts for about 25% of the U.S. energy consumption,[1] it consumes almost half of all petroleum products and is in itself 99% dependent upon petroleum.[2] In addition, the petroleum products used in transportation are generally refined from higher quality crudes, which are currently concentrated in the Middle East and Africa. This increases substantially the dependence of the transportation sector on petroleum products obtained from OPEC nations and from unstable nations throughout the world.

In the northeast corner of the United States, there is little indigenous energy supply, particularly those usable for transportation. Thus, virtually all petroleum products are "imported" from other States or from outside the U.S. A careful tracing of energy petroleum products in New York's transportation sector, for instance, shows that New York is over 72% dependent upon oil for its petroleum needs, compared to 43% for the U.S.[3] During the past decade, two significant shock waves have produced moderate supply shortfalls of 5% on an annual basis (but peaking to 11% on a quarterly basis) and associated price rises of 35-40%.[4] The effects of the latest of these shortfalls in 1979 has not yet run its course and are permeating the U.S. economy with significant ripples. With the precarious nature of international petroleum supplies and U.S. transportation system dependent upon those supplies, it is incumbent upon the U.S. to investigate the degree to which improved performance of our transportation system may reduce energy use, and the degree to which such performance can reasonably be related to the goals we have established for our transportation services. The purpose of this paper is to investigate such questions and to suggest some research that might be undertaken to sharpen our understanding of these problems.

A Definition of Performance

Generally the performance of a system, machine, or other entity is defined as the degree to which, or how well, it executes those functions required or expected of it. When the term performance is used with respect to an activity, we imply that standards are set such that performance can be measured. The setting of such standards implies a standard-setter, who introduces into the measuring processes his/her perception of (1) which variables or descriptors of performance are most relevant, (2) the relative weights to be assigned to such measures, and (3) the specific procedures to be used in determining the levels of such measures. Since different individuals or groups will have different views of not only the measures themselves, but also the relative importance to be placed upon them, no one viewpoint of performance is possible. In fact, numerous views of performance of transportation systems exist, depending upon the values and goals of the viewers and those who are setting standards. Similarly, we must understand that no measures of performance are truly objective, since they all incorporate subjectivity by the measurer concerning the above judgments. No one indicator of performance will suffice. Transportation systems performance, therefore, varies by context, by group affected, as well as by measuring device.

U.S. Transportation Energy Goals

The above discussion implies that the measurement of performance depends upon the goals of its measurers. The United States has a number of goals in transportation energy conservation:

- Increase the efficiency of vehicle movement such that a lower rate of energy is consumed per unit of work performed or mobility provided;
- Reduce absolute as well as relative dependence of the transportation sector on foreign oil;
- Promote efficient development of urban forms, such as that transportation systems may operate more efficiently;
- Reduce the absolute and relative costs of transportation energy, to keep such costs as low as possible, particularly for consumers;
- Over the longer term, ensure flexibility for conversion to alternative forms of energy, most particularly non-petroleum based;
- Achieve the above without significantly retarding the U.S. economy, or jeopardizing its national security.

Clearly, no one set of viewpoints can simultaneously account for all of the concerns of different groups within our society. These primary groups are: consumers, business and industry, transportation providers, and government.

Consumers

The largest set of viewpoints is that expressed by individual consumers. We wear different hats in the course of our days, but with respect to the transportation system, the most important hats we wear are those of (1) drivers and riders of vehicles, (2) owners of vehicles, (3) users of public transportation, and (4) taxpayers. While it might seem that consumers are intrinsically concerned about transportation, that is not necessarily the case. A number of polls, including those conducted in New York State, show that consumers generally do not view transportation as a particularly important problem for their community.[5] Table 1, for instance, indicates that among typical community problems, transportation is mentioned as most serious by less than 12% of the population (surprisingly, it is highest-ranged in rural areas). Crime clearly was identified as the most important problem, while transportation was essentially even with unemployment and drugs. Even in the transportation sector itself, most focus is upon the availability and infrequency of transit services rather than on the performance of the broader transportation systems of highways and private vehicles.

TABLE 1

PUBLIC VIEWS ON TRANSPORTATION IN NEW YORK STATE, 1974

MOST SERIOUS COMMUNITY PROBLEM

Problem	%
Crime	28
Unemployment	14
Drugs	13
Transportation	12
Pollution	7
Health Care	6
Others	19
None	1
	100

MOST SERIOUS TRANSPORTATION PROBLEM

Problem	%	Reasons
Local Bus	33	Availability, Frequency, and Dependability
Local Transit	16	
Intercity Bus	12	Availability and Frequency
Intercity Rail	12	
Highways	9	Pavement Condition
Pedestrian & Bike	7	Availability
Other or None	11	
	100	

Source: Reference 5.

Generally transportation service is viewed by most consumers as a ubiquitous commodity that should be available in reasonable quantity and quality, and is generally unquestioned with respect to supply or price. As vehicle operators, consumers want no traffic disruptions and other transportation concerns. They want to have traffic operate smoothly and in uncongested fashion, with reasonable operating costs. This implies that highway systems be in reasonably good shape, consistent with the public's ability to pay for them, and that unnecessary facilities not be built. As purchasers and owners of vehicles, consumers are particularly concerned about fuel economy and the trade-offs between purchase price and fuel economy. Maintenance of vehicles and the capability of the vehicle to sustain a useful life over a reasonable period are also important concerns among consumers. But few consumers are willing to cut travel as a mechanism for saving transportation energy (Table 2). Our data in New York show that most consumers would rather have incentives provided, particularly with intercity and urban transit use, rather than have reductions imposed upon their mobility. If actions to reduce travel are necessary, consumers prefer incentives rather than stringent measures.[6]

TABLE 2

CONSUMER VIEWS ON ACTIVITIES TO CONSERVE ENERGY IN TRANSPORTATION

ENCOURAGE TRANSIT USE		ENCOURAGE INTERCITY TRAIN OR BUS		TO REDUCE USE OF HIGHWAY FUEL	
Activity	%	Activity	%	Activity	% AGREE
Increase Service	31	Improve Service	85	Carpool Incentive	91
Reduce Fares	22	Lower Fares	81	Enforce 55	91
Police Protection	20	Incentives to Business Travel	69	Improve Traffic Flow	90
Improve Comfort	13	Higher Auto Tolls	22	Trip Planning	87
New Equipment	2	Higher Plane Fare	13	Shop Closer of Less	78
All The Above	12			Limit Car Size	59
				Small Car Rebate	58
				Tax on New Big Cars	52
				Rationing	32
				Higher Fuel Prices	12

SOURCE: See Note 6.

Not all consumers are transit users, but a significant number of the residents of large metropolitan cities do use transit at least occasionally. A number of analyses have shown that the primary factors influencing consumer perception of transit service are its availability and its quality, particularly its safety and security. Comfort is a more important concern for higher-income consumers. Reasonable fares are a must, but consumers are also reasonable in realizing the fares cannot remain fixed while inflation increases the costs of other commodities.

Most consumers are also taxpayers. They recognize that transportation services are not free, and require, therefore, that they be provided at reasonable (preferably low) tax rates. Government is expected to use such funds efficiently. The general lack of furor about transportation investments, except for specific proposals, suggests generally that consumers are reasonably supportive of the current procedures under which transportation investments are made and the rationale for such procedures.

Business and Industry

We get a slightly different view if we look at the energy conservation of transportation systems from the point of view of business and industry. As retailers and manufacturers, businesses are concerned about the capability of transportation systems to provide low delivery costs and easy access to specific sites, particularly by purchasers of their goods and services. Since the United States is a nation thriving upon interregional productivity, such concerns are also important for many businesses. Businesses are also employers and, as such, concerned with site access by their employees, particularly in the probability of energy contingencies.

Transportation Providers

Transportation providers are also concerned with low transportation delivery costs for their services and require access to sites. They also are concerned with the adequacy of particular vehicles to satisfy various fleet requirements. A particularly important group of providers, automobile manufacturers, are concerned about the importance of vehicle fuel economy as a selling point for vehicles, and the trade-offs between the price of vehicles and fuel economy.

Governments

Finally, governments in their various forms are also concerned with transportation systems performance. The responsibilities of the Federal Government include concern about foreign oil dependence and defense, reduced use of gasoline by consumers, and preparation for the possibility of energy contingencies. These concerns are mirrored by State and local agencies which may also have operating responsibilities for transportation systems.

Criteria for Performance Indicators

Measuring the energy efficiency of transportation systems performance requires that we identify indicators of performance which meet the following criteria:

- Relevant to both energy use and system activity;
- Detailed and explicit measurement;
- Timely information that is of use to us;
- Based upon available, rather than unavailable information;
- Accurate in measurement and precise in the degree of detail provided;
- Comprehensive in that the measures cover a large portion of systems performance activity;
- Diagnostic in that problem areas can be identified with such tools;

- Predictive, in the sense that the use of such measures may allow the identification of upcoming problems;
- Cost-effective in that the usefulness of performance indicators is considerably greater than the cost and difficulty involved in their collection and compilation;
- Continuously available so that trends may be observed;
- Unobstrusive so that citizens and society may not be unduly infringed upon by the collection and use of such data;
- Equity-sensitive in that measures allow for identification of arising problems within subgroups of society;
- Sensitive to external impacts, so that critical second order effects associated with system performance are identified in advance;
- Privacy-sensitive, imposing no restrictions upon individual freedoms and privacy in its collection or use.

Measuring Performance

Clearly, a large number of transportation systems performance indicators may be constructed which satisfy all or, more likely, part of the above criteria. Table 3 suggests a number of important indicators of performance which are generally available and quite useful in identifying certain energy-related characteristics of transportation performance. We must recognize that these characteristics relate only loosely to the viewpoints of different users described above. Among the most basic of performance indicators are those dealing with the amount and density of travel on transportation systems, the quality of the system itself, and the rate at which the system is using energy. While these variables are generally available, most are not collected by State or local transportation agencies as part of performance assessment. Such measures tend to concentrate on highway condition, speed, and traffic density rather than energy consumption. Clearly, such measures have little direct relationship to energy use, conservation, or efficiency.

The measures of changes in Table 3 clearly suggest that the quality of transportation service is declining, while energy consumption may have peaked and is being reduced slowly. Table 4 shows changes in key measures of transportation systems use and performance in New York State over the past decade. Taken together, the measures suggest increasing density of traffic (and hence congestion), declining highway investment and hence a slowly deteriorating physical plant, but improving average vehicle efficiency and declining per vehicle use. While all such generalities are subject to exceptions, this author believes that the following general statements can be made with reasonable certainty.

TABLE 3

ENERGY-RELATED INDICATORS OF TRANSPORTATION PERFORMANCE

PERFORMANCE INDICATORS

FACTORS	NATIONAL	STATE	LOCAL
Travel	National VMT	State VMT	Local Counts
Congestion	Speed Distributions	Speed Distribution	Average Speed
	Traffic Density	-----	V/C Ratio
Fuel Use	Fuel Sales	State Sales	-----
Price	Fuel Prices	State Prices	Local Prices
	Percent Consumer Income Spent on Transportation	-----	
Fuel Economy	National Corporate Average Fuel Economy (CAFE) New Cars	State CAFE	-----
	Vehicle Registrations	State Registrations	-----
Finance	Highway Maintenance Indicators	Same	-----
	Transportation Price Indices	-----	-----

- Travel has been increasing and is likely to continue to increase, in spite of energy constraints. Though energy prices are likely to rise, improvements in the efficiency of vehicles will partially offset these prices. Further, freedom of mobility will be discovered to be a particularly important goal in the lives of Americans.[10]

- Clearly not much additional highway capacity is likely to be added to the U.S. transportation system in the next decade, or perhaps even in the next twenty years. In fact, deterioration of the physical plant, which appears likely since costs are not able to keep up with revenues, is likely to result in a decrease of effective capacity on many sections of the transportation system, particularly older interstate systems.

- The costs of transportation maintenance and rehabilitation are likely to rise more rapidly than inflation, and significantly more rapidly than transportation revenues. As a result, the abilities of transportation agencies to improve the physical characteristics of their systems will become more and more difficult over time, at precisely the same time when transportation demand, measured by travel, will increase.

- The net effect of these factors is that improvements in vehicle fuel efficiency may be offset by increases in travel, and by deterioration in average speed and in the operating efficiency of vehicles over the road. The extent to which this trade-off will result in positive or negative energy consumption in the next decade is not clear.

TABLE 4

CHANGES IN TRANSPORTATION SYSTEM PERFORMANCE IN NEW YORK STATE, 1969-1979

FACTOR	% CHANGE 1969-1979	INFERENCES
Vehicle Miles of Travel	+ 20%	Increases in congestion, as VMT continues to increase, while capacity mileage does not, and as real investment (in constant dollars) decreases.
Gasoline Use	+13%	
Vehicle Registrations	+20%	
Highway Disbursements	+69%	Increased fuel efficiency and decreased use per vehicle, but offset by growth in total number of vehicles.
in Constant Dollars	-40%	
Highway Mileage	+ 4%	
		Declining highway investment, in real dollars, of 40% infers declining highway performance.

SOURCE: Highway Statistics, Federal Highway Administration (U.S. Department of Transportation), Highway Statistics Division.

The measurement of performance, even with such crude indicators as described in Table 4, suggest clearly that troubles lie ahead. It is likely that transportation analysts will not be able to predict, analyze, or respond to such troubles if they do not have available a number of sensitive and useful performance indicators that can be monitored over time. As described earlier, the number of such indicators that may reasonably be constructed for different levels of government is obviously quite large. Typical indicators have been constructed recently for the development of "leading travel indicators" as part of an ongoing study at NYSDOT.[11] The structure of these indicators is generally easy to understand, and work is currently proceeding to develop these measures further and to promulgate their measurements periodically to transportation planning agencies in New York State. As an example of this work, monthly newsletters have summarized transportation energy and travel statistics in New York State, with accompanying charts and numerical data.[12] This is pretty basic, but it is a start.

Research

We should include with this discussion a number of suggestions for research that would sharpen our understanding of the relationships between transportation systems performance and energy consumption. Let me modestly suggest the following:

- A clear, understandable, and precise definition of transportation systems performance should be developed so that the term denotes a clear meaning to all users of such terms. As the above analysis suggests, that definition must account for the different viewpoints of different actors.
- The need for clear annunciation of such goals is critical if we are to proceed beyond the talking point to the measurement of goal attainment.
- The Federal government should support the development of measures of transportation systems performance and the collection of data describing such measures. This issue is particularly critical in the face of deregulation, as many data bases currently available describing use and prices for transportation systems will no longer be available to agencies or consumers. The lack of such information is likely to lead very rapidly to a radical shift in our ability to even measure the degree to which transportation systems are being utilized, let alone performing in some optimal fashion.
- Measures of transportation systems performance must be related to energy consumption. We need to understand more than whether travel is increasing, costs are increasing, maintenance costs are not keeping up with inflation, or pavements are deteriorating. We must understand precisely the degree to which such trends influence energy consumption now and are likely to influence them in the future. As an obvious example, one might cite the basic study relating the characteristics of pavement conditions to vehicle energy consumption.[13] That study, completed over ten years ago, was based upon an exceedingly small sample of vehicles and drivers, yet it remains today a single critical piece of research underlying most of the analytical work in pavement condition and energy use. That study needs to be updated.

Summary

In conclusion, the following points can be made:

- The performance of surface transportation systems is probably deteriorating.
- Disparate views about the nature of this performance and its importance have contributed significantly to lack of progress in understanding the extent of this deterioration.

- Rising costs and constraining finances on the parts of governments are likely to make even more critical our ability to measure such performance and to identify critical segments of our system which are in need of our attention.

- Concerns for energy consumption are likely to further raise the spector of performance measurement even greater, since deteriorating transportation systems are likely to offset whatever gains we may make in fuel economy. The implications for foreign oil dependence and national security are, therefore, significant.

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PRIORITIES IN THE FIELD OF ENERGY RELATED TO TRANSPORT

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Introduction

Before starting my lecture on the principal theme, priorities, I want to consider some general items.

Energy conservation is a misused expression for the problem we are talking about today. The proof is simply given by the fundamental physical law of energy conservation, which is: "although energy can be changed in form it can be neither created nor destroyed."

We are really talking about conservation of the limited fossil energy resources in order to avoid depletion of these resources. (See Figure 1) However, we can only postpone depletion, not avoid it. When fossil energy resources are used on a large scale, even if less than is used today, depletion will be the result. Mitigating the use of fossil energy resources can only postpone moment of depletion, "doomsday," which will occur later in the future. Depletion of fossil energy resources will not only be a disaster for the supply of cheap energy, but also for the production of all sorts of hydrocarbons.

Figure 1
PRIMARY ENERGY RESOURCES

Earth based	oil gas coal	chemical
	nuclear geothermal	physical
Sun-based	wind waterpower biomass beaming	
Cosmic	(the spinning of the earth, etc.)	

To a great extent, the problem is not today's problem, but a problem for the (near) future. We can discuss it, but it is difficult to imagine what the repercussions on everyday life will be when depletion is nearby. A sketch of everyday life in such a situation will perhaps be an eye-opener for many people. I will not speak on this subject today, but will confine myself to priorities in the field of energy, especially those related to transport.

I do not expect to give mature solutions for the energy problem. I have opted to look at the problem in a way other than the usual one. The result may be that at the end of my lecture, you will say I have posed more questions than I have resolved. Then the only consolation will be that questions have to be posed before the answers can be given.

I will start with the problem of priorities in general, both short-term and long-term and continue with an application in the field of energy in relation to the transportation sector.

Priorities in Time-Perspective

In current circumstances priorities are to a great extent influenced or suggested by:

- the mechanics of the market,
- short-term expectations, and
- substitution possibilities.

Priorities are either not affected or barely affected by long-term considerations, or by long-term possibilities for substitution. The market-mechanism, which is for the most part a balance between supply and demand, is very important as a determinant for the volume used of different kinds of material. Expectations on the short-term can influence the market-mechanism. If scarcity is expected on the short-term, the price may go up due to demand-pull and/or supply-hesitating reactions. When an abundance is expected, prices may go down due to a supply-push and/or a hesitating demand. Substitution possibilities, (partial or total) between raw materials add an extra dimension to the market-mechanism. Shifts between products or services can weaken the market-mechanism for a certain product or service.

In my opinion, the minor influence of long-term situations is due to the diminishing effect in time-perspective. Situations far ahead in the future are vaguely or not at all recognized. In general, mankind hesitates about future development and about taking measures now, with a view to the long-term future.

In some respects there is a certainty about the depletion of certain raw materials in the future. However, we are not sure about the date of doomsday or the moment of depletion. A fatalist resigns himself to his fate; a rationalist looks for an escape. I will take the rational way which focuses on possibilities for substitution, both now and in the future.

Priorities in Substitutional Perspective

In order to make myself clear to you, I will start by analyzing a simplified hypothetical situation with sufficient marks of recognition in practice. In my example four raw-materials or resources are available, M_1-M_4. Out of these raw materials different products and/or services can be produced. These products/services are partly substitutional and can be divided into four groups, each satisfying a basic need in one way or another. These four groups of mutual substitutes we call A_1-A_4. All possibilities of production from the given raw materials are exposed in a matrix, in Figure 2, by mentioning the price of a unit satisfying one substitute of A_1-A_4. The higher the price, the higher the index of the price. Comparison of prices is only appropriate per column because of the mutual substitution possibilities within a column.

Figure 2

PRICES OF GOODS/SERVICES MADE OUT OF FOUR RAW MATERIALS, SATISFYING FOUR BASIC NEEDS

Basic needs / Raw Materials	A_1	A_2	A_3	A_4
M_1	P_6	P_4	P_2	P_1
M_2		P_8	P_9	
M_3			P_7	P_5
M_4				P_3

In our special case the lowest prices in all columns are at the top of each column. Therefore, due to the market-mechanism, the products made out of M_1 will be preferred. Additional suppositions of my example are:

1. The raw material M_1 is doomed to depletion in 20 years when consumption goes on in the same way.
2. A_1 takes only 20% of M_1.
3. The raw materials M_2, M_3, and M_4 are not limited by depletion within hundreds of years.

If a_1 is not an essential product or activity for society, depletion of M_1 has no really substantial fatal effect. However, when A_1 is lack of an essential basic need, lack of M_1 will frustrate the economy or society as a whole, and measures have to be taken to:

- postpone depletion of M_1, or
- initiate research and development in order to look for products and services based on another raw material than M_1 which can satisfy the basic need A_1.

Theoretically, postponement of depletion is very simply achieved when the production out of M_1 for the satisfaction of the needs A_2, A_3, and A_4 is cancelled. The need A_1 on the present level is then guaranteed for 100 years instead of 20 years. It also means a big breathing space for research and development in the mentioned way.

Cancellation of satisfying A_2, A_3, and A_4 out of M_1 in this case is only possible by accepting higher prices for this satisfaction. It means sacrifices now against gains or possible gains during a longer period. What will be gained depends on the results of research and development in the coming period and the moment that a result will be attained. It is hard to predict when that will be.

When no cancellation as formentioned is effectuated the scarcity of M_1 will much more rapidly increase. This will lead to increasing prices for the products made out of M_1. Successively, there will be substitutions in the columns of A_2, A_3, and A_4, and the claim on the raw material M_1 will decrease. Due to this effect the earlier mentioned period of 20 years for depletion of M_1 is an underestimate, but nobody can tell if the rising price of M_1 will have a devastating effect on the basic need A_1.

If A_1 is an indispensable good or activity, the world must concentrate its efforts to continue satisfying this need in the future. The only solution is to find substitutes before M_1 is depleted. So future life depends on human contrivance. When depletion is nearby, it will be a tough race against time. In reality, we hardly know when the race for a substitute which is able to satisfy the need of A_1 has to be started. To be on the safe side, we can never start too early. To avoid any risk at any price, we ought to keep all M_1 exclusively for the production of A_1 from this moment.

Priorities Related to Transport

With the foregoing theoretical approach in mind, we now will concentrate on transport.

- Transport is an indispensible activity; lack of transportation facilities would reduce not only our personal movement possibilities, but also trade and industrial activities.

- Transport can be seen as the bloodline of our economy and social life. If transport is restricted, the economy will be disrupted and many social links broken.

- Transport is an activity which is almost 100% dependent on fossil oil as the most important raw material. Nearly all inland navigation, nautical and the aeronautical fleets, and nearly all cars and trucks are dependent on oil.

The relationship between transport and fossil oil is like the relationship of A_1 to M_1 in the former paragraph. The time has come to reconsider priorities in the field of oil-consumption. So we have to give top-priority to transport in that respect, at least until a real good substitute is available for fossil oil as a raw material for transport? If no really good substitute would be available when the depletion of oil occurs in the future, priorities must be shifted in order to prevent the society as a whole from being adversely affected. With this in mind, it is clear that our efforts in research and development to create a substitute fuel must have a high priority and must continue.

To avoid misunderstanding, this is not a plea for top priority for all transport, but only for the component that is indispensible and needed to keep the heart of society beating.

Mobility can, to some extent, be reduced. Less oil-consuming transport facilities will rank high in periods of oil-scarcity, and telecommunications will be favored as a substitute for some trips.

Many products are made from petrochemicals, although in many cases very good substitutes which do not use oil are at our disposal. Perhaps the time is ripe to reconsider our priorities. All depends on our expectations about the development of substitute fuel during the coming decades.

Epilogue

I have spoken about transport and its indispensability, the crucial raw material (oil), and the need for substitute fuel before the depletion of fossil oil. If the strained situation evoked by the OPEC countries raising the price of oil results in the development of a substitute fuel in due time, what is now a scourge for many countries will become a favorable situation for all of us.

ENERGY EFFICIENCY IN TRANSPORTATION:
PROBLEMS IN DEFINING AND ASSESSING PERFORMANCE INDICATORS

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Introduction

During the 1970s numerous efforts were made to rank various transportation systems in terms of energy efficiency. The time has now come to evaluate experiences with methodology and results.

Any serious efforts towards using studies of energy efficiency for investment purposes require studies of energy requirements for propulsion, for constructing and maintaining moving equipment, and finally, for building and operating infrastructure. For decision purposes, and with recognition of their impacts for decades, one has to be aware of technological development, especially of the kind that influences energy requirements for propulsion and energy requirements for moving equipment. Technological progress in constructing infrastructures will probably be of less interest because of the large time span.

This paper focuses on problems connected with defining and measuring appropriate performance indicators. It is stated that there exists a number of pure technical problems when considering what and how to measure. It is also shown that simple yardsticks of energy efficiency, like modal average intensities expressed in kWh/tonkm and kWh/passkm, cannot be used as a base for assessing, for example, energy savings due to modal shifts. One reason for this is the fact that significant marginal changes in modal split will not relate to average performance. Support to this claim is given by a number of examples showing that energy efficiency within any single mode shows greater variations than the differences between modal averages.

Available Data Sources for Determining Propulsion Efficiency

It is not quite obvious what standards should be used for determining energy efficiency in propulsion for various transportation means. Energy consumption by passenger cars is the largest part of energy consumption in transportation. Passenger cars account for about 80-90% of energy consumption for passenger transportation in most industrialized countries. One approach is to accumulate the entire gasoline consumption in a country on a yearly basis and divide it by the total mileage driven, vehicle category by vehicle category. The first problem, but probably not the largest, is that no country can determine the exact part of gasoline consumption that is ascribable to automobiles. But, because gasoline consumption for driving cars is such a large portion, this will not be a serious problem. The other problem is the inaccuracy in estimating the average miles driven. In the U.S., for example, for many years this mileage has been estimated to be 10,000 miles per car, but nobody is certain about this figure. In Sweden average miles lie around 14,000 kms and this figure is based on samples taken during most years in the 1970s. I estimate the uncertainty in mileage to be in the order of ±10%. One has to bear in mind that all the errors and uncertainties are cumulative. However, this is not too significant on a national level.

A larger problem lies in the distribution of all the variables of concern. For example, annual mileage has a wide distribution between cars. Also the size of the car, engine size and type, and other technical properties are important. This latter can be overlooked to some extent on a national level. But when it comes to determining the most efficient system and especially the most effective future system, one must consider all the possibilities for improving performance. This means that if we enlarge the share of the best existing car today, then the national average will be influenced.

In order to get a realistic view of the use of passenger cars, one might use the results of various test procedures, as applied by the Environmental Protection Agency (EPA). The results of these procedures, featuring a miles per gallon figure, result from a test procedure that reflects the weighted average between the so-called urban driving cycle and the highway driving cycle. The vehicle is mounted onto a testing device that simulates the driving patterns of urban and highway driving. These procedures were applied to new cars in the mid-1970s, but the test results make the cars look far too good. According to my own computations, where I used the EPA results on the Swedish car fleet and used other data applicable to Swedish conditions, my findings indicated that the specific energy consumption (liter/km), was 10-20% too low compared with real conditions. Besides the suspicion that the driving cycles used in the EPA procedures are not realistic, as they were chosen from the Los Angeles area, I conclude that weather conditions (and particularly the use of spiked tires), outdoor temperatures, accessories and unsatisfactory maintenance explain the discrepancies. Nevertheless, protests declined after the automobile industry found that a "good" test result could be used as a selling argument.

There also exist some European testing procedures that can be used. For example, the ECE-cycle is similar to the EPA procedure and the German DIN-standard which since 1978 related to the ECE-cycle, but earlier tested gasoline consumption under certain conditions at constant speed. Furthermore, most self-respecting motor magazines test interesting new cars. Although I believe several of them offer reliable data, they are not able to test all types of cars every year. This is, of course, a shortcoming.

When it comes to mass transit, the situation becomes quite different. For companies providing bus service one can use gross statistics like quantities of fuels and mileage over certain periods which offer the possibility of computing average figures for the period. However, it is much more difficult to estimate the number of passengers transported. One example is the Stockholm area's sale of periodic tickets which makes it impossible to compute passenger services using the number of tickets sold. (In intercity operations it is easier.) Still, most available figures relate to average conditions and give no picture of the variations that occur.

Another problem is that the same type of bus can be used for suburban duty as well as for rural services. However, the energy consumption records will vary greatly. Because buses are used for different services within a company, accurate data for specific service and traffic conditions is difficult to obtain.

In rail transportation, records usually are kept for diesel-powered operations. However, in Sweden more than 90% of transportation work is performed with electric power which complicates the matter of accurate records. Statistics are available on the amount of current used, but consumption by a single train is not possible to measure without special equipment which is rarely used.

In maritime transportation each vessel registers the exact number of bunkers used for each journey. It is, therefore, possible to compute the amount of bunker oil used for any trip. However, our studies show that variations are very great depending on weather conditions (wind and waves), amount of cargo on board and whether measures have been taken for slowsteaming or not.

For air transportation, variations similar to those for shipping can be considered. Accuracy is even greater because of safety regulations. Important factors are load, wind conditions, and air speed.

Besides the lack of appropriate data on transportation and energy consumption, comparing various propulsion systems is difficult. The simplest example is the difference between gasoline and diesel fuel. Diesel oil has a higher density. One liter or gallon of diesel contains more energy than the corresponding volume of gasoline. The difference is about 10%. Similarly, the difference between high and low octane gasoline depends mostly on the content of lead. Lead has a very high density and gasoline containing lead will appear to be more energy efficient if measured by volume, but not necessarily when measured by weight. But, when one includes more efficient high-compression engines, it is obvious that high octane gasoline is more energy-efficient. However, when we include energy consumption, which occurs in the production of fuels, gasoline consumption is far more energy demanding than the production of fuels like diesel or heavy bunkers.

Comparing electric propulsion with combustion engines is much more complicated and important. We can generate electricity from hydroelectric, oil-fired or coal-fired plants, nuclear powered plants, etc. If one begins with the assumption that all electricity used for railway propulsion is generated from hydropower, it is seen that such a system is 2.5 times more efficient than one assumed to be using oil-fired plants.

Comparison is even more difficult in the case of nuclear power versus that generated in hydroelectric plants. How does one calculate the efficiency of nuclear power? Considered in relation to energy in uranium, the efficiency of a nuclear plant would be very low, although it may be maintained that this is of purely theoretical interest. If one considers the heat actually released in the reactor core, the efficiency would be about the same as that in a condensing plant (or maybe somewhat less, due to safety arrangements).

Performance Characteristics of Various Transportation Modes

A complete analysis must include not only the energy used for propulsion, but also that going into the manufacture and maintenance of vehicles and into the construction and maintenance of infrastructures. The energy inputs must be measured which means they must be converted back into comparable forms of energy and the measurements made at equivalent energy conversion points.

As may be seen from Chart 1, such an analysis is inevitably far ranging. On the left is shown a chain of conversion--from oil well via tanker to refinery, and then on to the distribution network--resulting in fuel for propulsion. Naturally, the quantity of energy in the calculation will depend on where in the chain of conversion the measuring point is placed--an especially complicated matter when it comes to comparing different forms of energy for propulsion.

The processes of manufacturing and maintaining moving equipment are shown on the right of the diagram. Here must be included not only the makers of the vehicles and their subcontractors, but also all the suppliers of materials. Consequently, an analysis of energy input must be carried back to the mine and the farm and the forest. Maintenance and repairing throughout the life of the moving equipment also requires considerable amounts of energy.

Thus, a thorough ongoing analysis of the relative efficiency of various modes will have to include factors that are not normally taken into consideration for such purposes. Moreover, various complications arise because different types of vehicles are being used for different purposes, which means that it is almost always wrong to compare modal averages. In analyses of this kind two problems particularly arise: where to set the limits as to what shall be included and how to quantify or otherwise valuate non-monetary items.

Regarding the items that are to be included, it is sometimes proposed that all the energy used for transportation, plus that consumed by all the suppliers to the transport industry, shall be taken into account. It has been claimed that about 30% of total energy consumption in industrialized countries, directly or indirectly, is ascribable to transportation. This is based on the sum of energy actually used in transportation and that consumed by other industries insofar as they are suppliers to the transport sector. The defect of such arithmetic is evident if one makes a similar analysis of all other community functions: total energy use would turn out to be well over 100%. It may be noted, however, that the method has been used mostly in attempts to show that the supposedly wasteful use of energy in transportation must be curbed at all costs.

Intercity Freight Transportation

Since the findings refer to conditions in Sweden, it may be well to note how transportation work is distributed amongst various modes. As will be seen from Chart 2, the highway modes dominate in both cases, and in general, the distribution is similar to that in most European countries.

The situation is much more complicated with regard to the railways. About 60% of the whole Swedish system is electrified, and about 94% of freight transportation work is done on the electrified lines. Trains drawn by electric locomotives are thus of major interest.

Among the conclusions to be drawn from analyzing intercity freight transportation in Sweden is that energy efficiency improves with increased utilization of capacity. Further, as the size of shipments increases, advantages of scale can be obtained by shifting over to modes that provide a greater capacity per trip. On the other hand, it matters little which mode of transportation is actually chosen. The degree of energy efficiency depends on the volume of freight and which mode allows for the greatest utilization of capacity.

It may be noted that all modes are approximately equivalent (with regard to energy efficiency) in the case of shipments up to 200 tons--provided the operation itself is carried out efficiently and the transport distances are the same. It would also appear from Chart 3 that railways and shipping are about on a level for shipments of 200 to 1,000 tons. Only when it comes to still larger freight movements, are ships definitely more efficient as regards energy consumption.

The question then is whether this general picture will be altered by including items other than energy used for propulsion--in other words, that energy which goes into the moving equipment and the infrastructure.

There is yet a further point to be noted with regard to infrastructure. Different parts of both road and rail networks are utilized to greatly varying degrees. In order to illustrate the effect of these variations, in each case the network has been divided into classes representing three degrees of traffic density.

The addition of infrastructure-related energies in the case of shipping makes only a negligible difference. This addition is greatest for railways no matter how the calculation is made. It is also evident that those sections of the railway and highway networks with lowest utilization show the highest total energy consumption. On such sections of railways, energy figures related to infrastructure can be shown to be actually greater than those for propulsion. Moreover, such sections constitute about 55% of the total rail network, whereas on highways they amount to very little.

Energy efficiency depends to a very high degree on capacity and on the extent to which that capacity is utilized. If a more efficient use of energy is to be attained in transportation, special attention must be paid to the way in which the flow of goods provides the conditions for the efficient utilization of both the moving equipment and of the infrastructure. It is worth noting, however, that energy efficiency can be improved by increasing the size of shipments, which in turn leads to the conclusion that with a limited flow of goods, it is best to confine traffic to a single mode. The costs for the infrastructures, in particular, underline the necessity of doing so.

For a significant share of all shipments, however, the consumption of energy is by no means confined to the main haul. Trans-shipments may take place both at the starting point and the destination, involving consumption by other vehicles and by handling equipment, in addition to that ascribable to the infrastructure. Therefore, an analysis has been carried out recently in order to determine the proportions of such consumption (for distribution, etc.) in various cases, for a complete transport.

In general, it may be noted that feeder and distribution transportation is done in smaller vehicles, involves extra handling, is carried out in several stages with a resultant rather low load factor, and is often in urban areas where congestion leads to a reduced rate of travel. Consequently, energy efficiency tends to be much lower than in the case of long-haul work.

Naturally, the proportion of total energy consumption that can be ascribed to this secondary transportation is greatest for shorter distances. For a distance of 200 kilometers, for instance, it could amount to as much as 35% of the total. Different results are forthcoming, depending on the factors involved. However, in general, it appears that the inclusion of secondary transportation greatly changes the break-even points between the modes, that the degree of utilization is again important, and in consequence the choice of the most efficient mode, overall, must be governed by specific circumstances that relate to the particular case at hand.

Urban Passenger Transportation

Passenger movement in urban areas can be classified according to starting points and destinations and according to the traffic conditions in which these movements take place. Trips may be made between the suburbs and the city center, within the central area, or from suburb to suburb. Obviously, the great differences between rush hour and the rest of the day affect capacity utilization and freedom from congestion. Besides passenger cars and buses, the modes that are considered here are the Stockholm subway and commuter trains.

In Chart 4 (representing commuter travel), the two sets of curves for the category, passenger cars represent a small vehicle weighing a total of 800 kilograms with the driver, and a larger one weighing 1,350 kilograms. Over 90% of cars on roads in Sweden fall within the spread between these two sizes. The mark-offs show energy consumption per passenger-kilometer at commuting times with a typical occupancy of 1.3 persons including the driver.

Of the two bus types represented, one is a typical single decker with space for 70-80 passengers, of whom a good half can be seated. The other is an articulated vehicle for 120 passengers. The circled parts of the curves show typical rush-hour load factors of 10-15, with about 20 passengers counted over the whole trip, from terminal to terminal. The reason for these relatively low figures is that the buses are only travelling full between a few stops, inwards in the morning and outwards in the evening.

The energy economies of the subway and commuter trains are about on par--the higher speed of the latter being counterbalanced by the shorter distances between stops on the subway. During rush hours the subway shows a load factor of 35-40% in the direction of the rush, and 10-15% in the opposite direction. The figure of 50-70% attained on the commuter trains is explained by the fact that they are better filled than the subway trains at the extreme ends of the lines (both systems run from suburb to suburb, passing through the center of the city). In both cases the load factor will exceed 100% on some section of the line.

The general impression is that rail systems are the most energy efficient, with buses coming second and cars last. At off-peak times, however, the picture is different. Car occupancy rises in the evening to about 2 persons, and with the absence of congestion, fuel consumption per passenger-kilometer improves. Despite the fact of less frequent trips, buses are less well filled in the evenings. Here again, however, the absence of congestion leads to better fuel economy. On subway and commuter systems the consumption of energy is reduced through the use of shorter trains--which does not, however, prevent the average load factor per car from falling. In consequence, buses and cars turn out to be about equally energy-efficient in the evening, while the rail systems show a higher consumption per passenger-kilometer than at other times.

Travel within the city proper has its own characteristics. During rush hour, energy consumption of cars is even higher than in the case above. Both buses and the subway show a high load factor and the previously noted differences between modes become accentuated. Under off-peak conditions, differences tend to even out. Cars show a lower fuel consumption and a higher occupancy. Better traffic conditions result in a lower consumption of energy for buses and for shorter trains on the subway. But, since the average load factor decreases as well, there is again a levelling out with the buses still retaining some advantage.

In the evening, after rush hour, the flow of passengers on buses and on the subway is extremely low, while cars can move more freely and have a relatively high occupancy. It would appear that under extreme off-peak conditions, cars are the most energy-efficient mode. The greatest variations, both relative and absolute, are shown by cars and rail. In the case of trains, the main reason for this is that neither system can adjust its capacity to passenger flow, particularly if any regularity of service is to be maintained. In the case of cars, the varying effects of occupancy and traffic conditions coincide in such a way as to have a maximum impact--fuel consumption being lower when traffic conditions are good at the same time that occupancy is higher, and vice versa.

Altogether the variations are so great that it is difficult to draw any clear-cut conclusions about what the net results of drastically changed urban travel habits will be. There would seem to be some possibility of saving energy if people used public transportation to a greater extent, rather than travel by car. But this would only be so if no new railway lines had to be built, or bus lines started--since the load factor would inevitably be lower on such lines than on existing ones. It should also be borne in mind that on the busiest parts of the existing lines capacity is already being utilized to the fullest. Therefore, any excessively drastic measures might lower travel standards to such an extent that the effect would be the opposite of that intended--resulting in lower average load factors and a higher consumption of energy per passenger.

It may be stated in conclusion that the greatest savings of energy are obtainable through a generally improved utilization of capacity. What is perhaps not so certain is how this is to be achieved.

Since cars are the overwhelming predominant mode of transportation in Sweden as in other industrialized countries, it would make sense to aim for an increase in average occupancy. It is here that the greatest and theoretically best potential for saving is to be found.

CHART 1

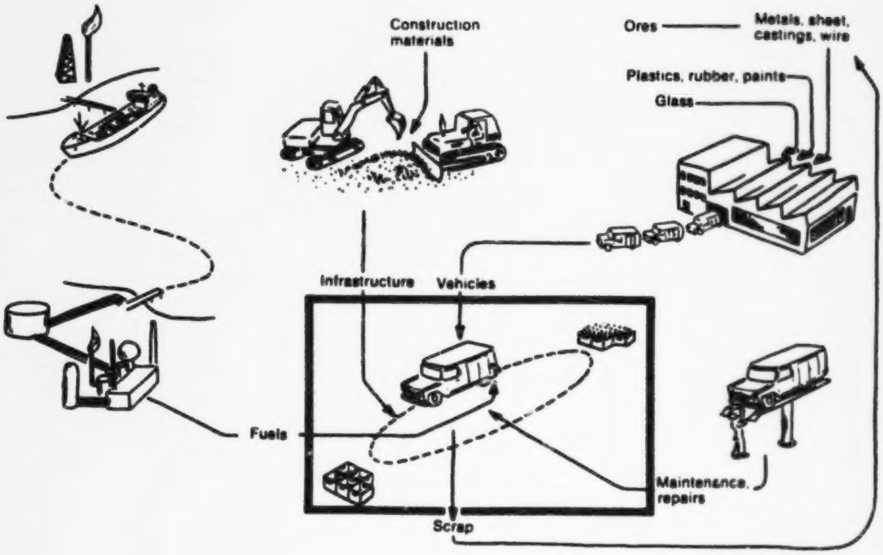
Construction materials
Ores
Metals, sheet, castings, wire
Plastics, rubber, paints
Glass
Infrastructure
Vehicles
Fuels
Maintenance, repairs
Scrap

CHART 2

TRANSPORTATION IN SWEDEN

Freight Transportation

Highway	46%
Rail	31%
Maritime	23%

Passenger Transportation

Passenger Car	82%
Bus	9%
Light Rail, Subway	1.5%
Rail	6.5%
Maritime	-0-
Air	1%

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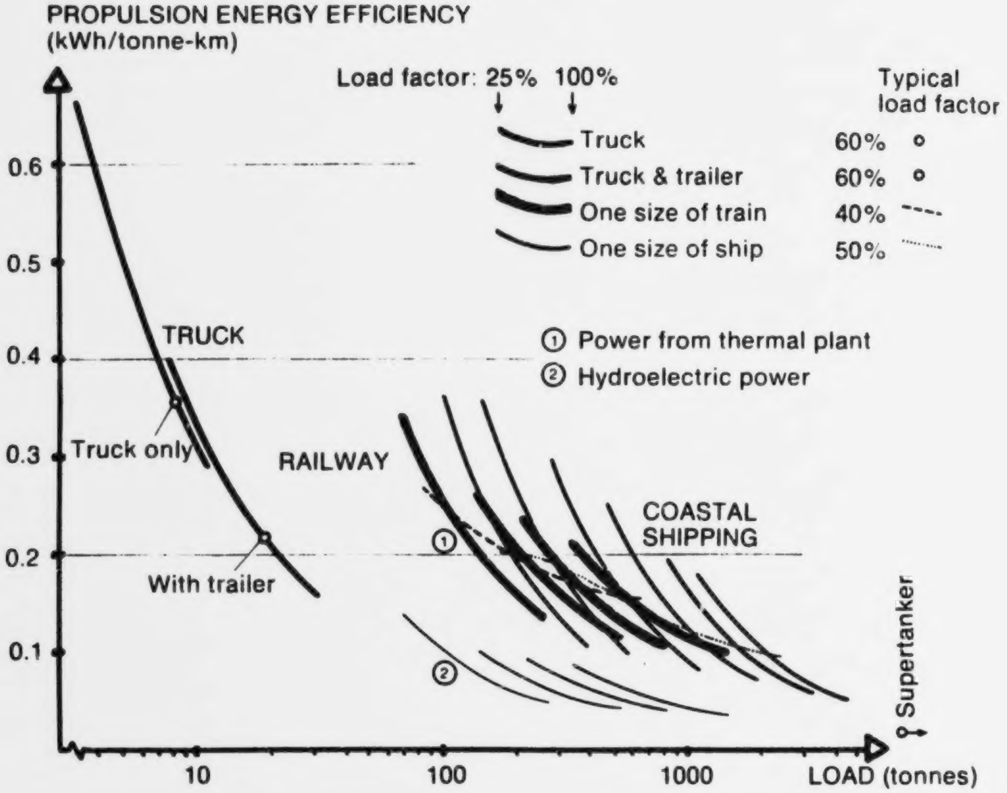
CHART 3



Intercity freight transportation. Propulsion energy requirements in kWh/tonne-km for various modes and sizes of vehicle/vessel with varying load factors.

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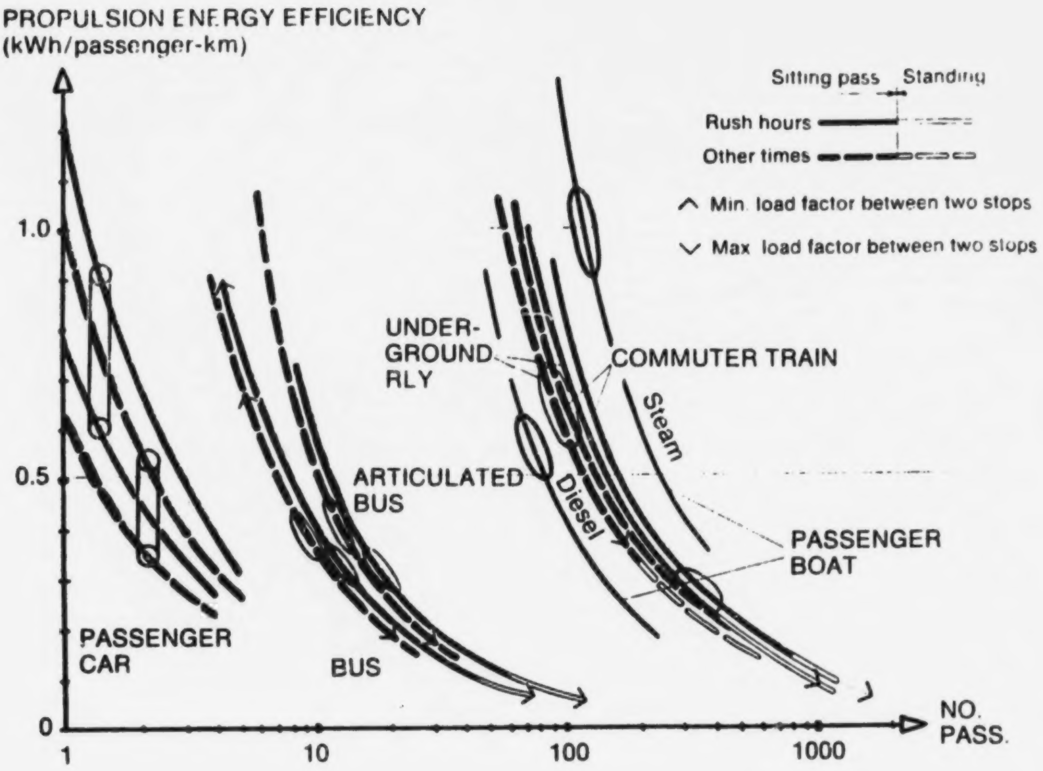
CHART 4



Urban travel, suburb to centre. Propulsion energy requirements in kWh/passenger-km for various modes and sizes of vehicle/vessel with varying load factors.

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EFFICIENCY OF TRANSPORT MODES IN THE NEW ENERGY ENVIRONMENT: THE POSITION OF THE RAILWAY

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Abstract

Knowledge of the energy efficiency of a mode of transport is based on the use of a set of indicators. The general quantitative indicators used today are insufficient; they obstruct the possibility of making valid comparisons for decisionmaking in matters of transport and energy policy. This insufficiency blurs the outline of each of the modes of transport exactly at a time when the energy panorama and its foreseeable evolution urges decisions to be made with speed and at the same time with prudence.

In connection with the preparatory work relating to a General Railway Plan, RENFE has developed a special system for evaluating the energy efficiency of the Railway. This system and statistics relating to RENFE's own experience are provided and some conclusions are presented.

General Approach

Summary

The new energy environment has an impact on all economic processes and requires an appropriate analysis to draw conclusions that will help rationalize transport planning. Transportation is among the sectors most affected by current energy problems. It may be affected even more in the future.

This study is based on the state of affairs in Spain and first examines the continuing energy crisis that dominates the world. This discussion is followed by an intermodal energy analysis of the transport sector based on gross performance (quantitative efficiency), degree of dependence (qualitative efficiency), adaptability to the productive structure (efficiency in time), versatility (technological efficiency) and economy (economic efficiency).

This analysis facilitates a systematic study of transport modes from the point of view of energy, and proposes a group of clearly identifiable and easily calculated indicators which should be considered in any comparative examination of different transport modes.

Energy Consumption Measurement Units

Although the usual physical units, Kwh, BTU, Kcal., etc., are sometimes used for measuring energy production and consumption, many publications express consumption in conventional units. Among them are some with nearly universal acceptance, such as Tec (ton of coal equivalent), which represents the energy that can be provided by a ton of solid fuel with a given calorific power which, in Spain, is considered as 7,000 Kcal/Kg, and Tep (ton of petroleum equivalent), which refers to liquid fuel.

Considering the average calorific power of petroleum as 9,800 Kcal/Kg. and taking into account the actual output of thermal power plants, the following approximate ratios of equivalence result:

1 Tec = 2,500 Kwh
1 Tep = 1.4 Tec

On some occasions when a global view is required, the unit E (Energy) has been used with the following equivalence:

$1E = 10^{14}$ Kwh

The ME (Middle East) can be included in a category representing the reserves of oilfields in that region, which total some 50 billion tons, with the following results:

$1 \text{ ME} = 70.10^9$ Tec.

Continuing Energy Crisis

Price Crisis

From the year 1 A.D. until 1850, the world consumed 25E. From 1850 to 1950 the world used 12E. From 1950 to 2050 a consumption of 1,000E is forecast. The worldwide consumption of oil was some 3.2 billion tons in 1980. In this extraordinarily accelerated rate of consumption, oil constitutes about 50% of the total of all energy consumed. The annual growth in the rate of consumption has been 3 to 4% which requires that production be doubled more or less every 18 years.

Of course, the continuous prospecting being carried out is producing constant successes--the North Sea, Mexico, Africa, Siberia, China--but in order to function, we must have 15 years of guaranteed coverage; we must discover new reserves of 1 ME, 2 ME, and 4 ME, etc., before 1990, 2000, and 2010, respectively.

To summarize, in order to guarantee supplies, the world must discover 3 new Middle Easts, that is 150 billion tons of crude, before the year 2000. Although this eventuality is basically possible, since total world oil reserves are calculated at 400 billion tons, certainly it will not be easy to bring 40% of these reserves into exploitation in a period of only 20 years.

Therefore, apart from any other consideration, oil will become increasingly more scarce as it is increasingly consumed so that oil prices will inexorably tend towards increasingly marked rises. The crisis experienced during the 1970s represents no more than the tip of the iceberg in a process in which general economic principles have been made explicitly manifest. Accordingly, the price of a product is in proportion to its scarcity; and thus humanity has experienced and suffered a drastic increase in the cost of crudes and their derivatives--the price of which has multiplied by more than 12 in the past 8 years.

Supply Crisis

While the effect of the increases in prices is serious and has made the world economic systems reel, the outlook can be even more serious if a supply crisis also develops. Everything seems to be pointing towards this hypothesis. Let us recall how the Ankara Conference, which was a meeting of experts from 15 countries, drew certain unanimous conclusions on the basis of preliminary work by MIT (the well-known WAES--Workshop on Alternative Energy Strategies--report). These conclusions, which can be summarized as establishing the critical moment of supply depletion in relation to different production strategies (keeping the 1977 level constant, increasing it by 50%, or raising it without limits), indicate that regardless of the strategy followed, from 1990 on, the world will have to consume less energy of liquid origin. World events, such as the political instability of the Middle East, the Iraq-Iran War, and others, may cause this critical moment to occur sooner.

Energy Analysis Of The Modes Of Transport

As we shall see, transport is a voracious energy consumer. In view of the scene we have just outlined, we must make a detailed analysis of intermodal energy behavior. If in the past we may have considered such detailed analysis to be interesting or purely academic, now it is essential.

Timeliness of the Analysis

Transport's share of total primary energy varies from one country to another, but it generally ranges between 12 and 20% in developed areas. In Spain, this figure has continued to rise in recent years and was 20% of the total in 1979. This high percentage rate gives rise to a dual problem:

1. On one hand, transport's share of primary energy has a clear tendency to rise or, at best, to stabilize. This supports the idea that we are faced with a structural inflexibility in the sector, with respect to the introduction of technical or other kinds of changes which, on a global level, could substantially reduce average consumption. Therefore, transport, because of its own internal dynamism, may not undergo important changes in the near future. The proportion of energy absorbed by the sector may be even higher than at present.

2. On the other hand, conditions are such that this 15 or 20% share of energy is, in the main, dependent on oil. In Spain, only two forms of transit, railways and subways, are oil-independent.

Therefore, transportation, which is key to economic and social activity in all countries, is especially affected by current energy conditions and is certainly most sensitive to any new disturbance that may arise. Thus, we must make increasingly better adjusted and more realistic multi-modal analyses of energy efficiency in transport, and, if necessary, use new indicators of energy efficiency to supplement the already existing indicators.

Difficulties in Evaluation

Within each mode, evaluating energy consumption is relatively simple, given a specific type of vehicle whose fuel, characteristics, and operating conditions are known. However, certain questions arise when we compare different transport modes with vehicles having different technologies or fuels, different technical characteristics (tares and loads), and different operating conditions.

To measure energy input (gasoline, electricity, etc.) we generally convert different classes of energy into a common denominator such as Tec or Tep. To measure output, we generally consider the volume of traffic moved by each mode. This method is open to attack by arguments which would prevent intermodal comparison on the basis that the units of measure are not homogeneous.

Recently the CEMT devoted a monographic round table to this issue. The debate over the issue involves a certain demagoguery, perhaps in some cases resistance to conceding validity to results which, at some levels, are uncontestable. That traffic units of one or another mode are or are not homogenous can be relevant to a certain level of aggregation. However, research has measured high elasticities in intermodal transfer compared with moderate variations of the corresponding tariffs. This fact makes it possible to consider traffic units developed from different modes as being perfectly comparable, at least at the global level.

The Need to Operate With Average Values

As a result of what has been said in the preceding section, we think that global comparisons should be based fundamentally on the study of average consumption variation. This approach would not create an obstacle to establishing energy evaluations with the greatest possible degree of exactness for specific projects and individual cases. However, this information should also be understood in the opposite sense, that is to say, the obligation to ensure that each specific project is as efficient as possible, from the point of view of energy, in relation to all its variables, should not prevent us from availing ourselves of general criteria which, on the basis of the study of average reference values, allows us to establish clear policy guidelines.

In brief, the problem is not that of abandoning the concept of average specific consumption of each transport mode as an element of comparison, but of extending its potential by including other indicators with which we can establish quantitatively reliable comparisons of different modes with respect to the energy problem as a whole.

Intermodal Comparison

Under the following headings is an explanation of the results of intermodal energy comparisons made by analyzing Spanish transport with an extensive range of indicators.

Gross Performance or Specific Consumption

Details of the actual values are given in Figures 1 and 2 in which indices of the efficiency of each mode are deduced on the basis of consumption. The resulting figures do not differ in their orders of magnitude from those that have appeared in various technical documents which, theoretically or practically, deal with the same problem in other countries (see Figure 3). The figures demonstrate a distinct advantage for the guided modes of transport with respect to other modes.

Another numerical indicator of differences in energy efficiency between modes is made through a comparison of traffic use to energy consumption. In particular, the Spanish railway, which carries almost 10% of the total volume of traffic, consumes only about 4% of all energy used by transit (see Figure 4).

Another approach is based on the hypothesis that the traffic borne by one mode has to be accommodated by other modes. Thus, a measurement of the contribution made by each mode, to solving or aggravating the energy problem, is obtained by analyzing the differential energy balance between modes. In the case of Spain, if current railway traffic had to be accommodated by other land transport modes, the country would face an incremental energy consumption of more than half a million Tec per annum.

Energy Dependence

Today economic sector dependence on liquid fuel, even apart from price, is a disturbing factor since it either imposes an undesirable bottleneck that may restrict supplies or, when oil products are available, exerts serious pressure on them.

Spanish transport, as a whole, depends on liquid fuel for 98% of its energy requirements because virtually all (97%) is consumed directly in liquid form.

The production of electricity for transportation requires about 25% of the liquid fuel allocated to transportation. Electricity, in turn, supplies only about 3% of the energy required for transportation. Road, sea, and air

FIGURE 1

PASSENGER TRAFFIC

SPAIN 1979

MODE	TRAFFIC 10^6 P-K	ENERGY CONSUMPTION		CONSUMPTION EQUIVALENT 10^3 TEC	AVERAGE CONSUMPTION		ENERGY EFFICIENCY	
		Electricity 10^6 Kw-h	Liquid fuels 10^6 litres		GEC/P-K	Index	PK/Kgec	Index
Railway Renfe	16.609	513	95	319	19	100	52	100
Underground Madrid (1977)	2.663	203	-	81	30	158	33	63
Urban buses E.M.T. Madrid (1977)	1.543	-	41	49	32	168	31	60
Road Cars. Motorcycles Motor coaches National Total	197.500	-	8.393	10.072	51	283	20	36
Air transport	6.256	-	661	793	127	669	8	15

FREIGHT TRAFFIC

MODE	TRAFFIC 10^6 T-K	ENERGY CONSUMPTION		CONSUMPTION EQUIVALENT 10^3 TEC	AVERAGE CONSUMPTION		ENERGY EFFICIENCY	
		Electricity 10^6 Kw-h	Liquid fuels 10^6 litres		GEC/T-K	Index	TK/Kgec	Index
Railway Renfe	10.592	539	106	343	32	100	31	100
Road Total	99.500	-	4.468	5.362	54	169	19	61
Sea routes Coasting trade (1977)	29.042	-	854	1.025	35	109	28	90
Oil pipelines	2.786	113	7	54	19	59	52	168

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FIGURE 2

EVOLUTION OF SPECIFIC ÉNERGY CONSUMPTION (G.E.C./UK) IN ROAD, RAIL AND AIR AND IN INTERIOR TRANSPORT

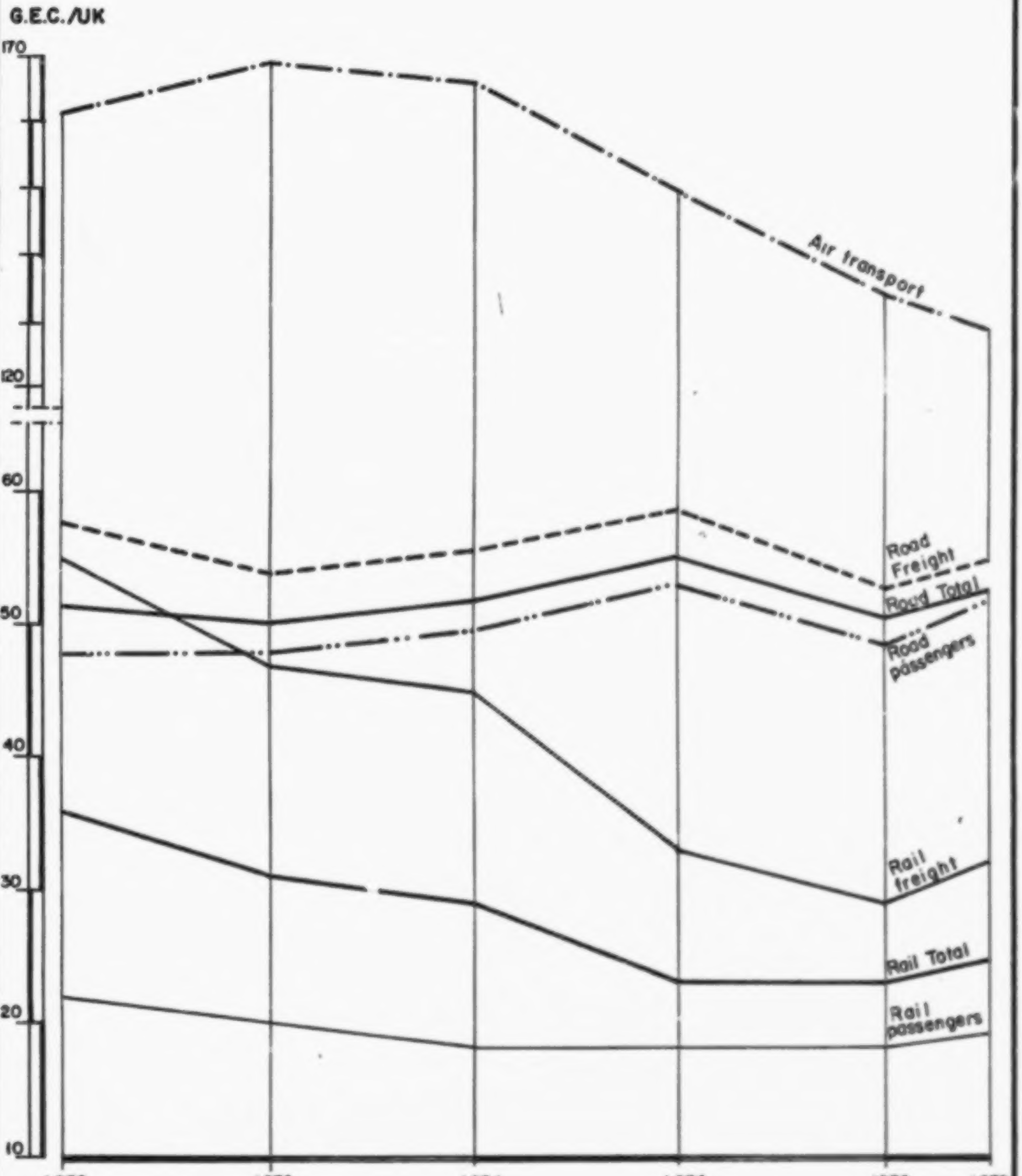

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FIGURE 3

TRAFFIC AND ENERGY CONSUMPTION IN THE TRANSPORT SECTOR

SPAIN 1979

	ENERGY CONSUMPTION (in 10^3 TEC)	TRAFFIC	ENERGY	TRAFFIC
PASSENGERS (10^6 PKm)				
Rail	319	16.609	2.9	7.5
Road	10.072	197.500	90.0	89.6
Air	793	6.256	7.1	2.9
Total	11.184	220.365	100.0	100.0
FREIGHT (10^6 TKm)				
Rail	343	10.592	6.0	9.4
Road	5.759	99.500	93.1	88.1
Oil Pipeline	54	2.780	0.9	2.5
Total	5.759	112.872	100.0	100.0
TOTAL (10^6 UK)				
Rail	662	27.201	3.9	8.1
Road	15.434	297.000	91.0	98.1
Air	793	6.256	4.7	1.9
Oil pipeline	54	2.780	0.4	0.9
Total	16.943	333.237	100.0	100.0

SOURCE: Annual Reports of Renfe, Institute of Transport Studies and Communications of the Ministry of Transport. Compiled by the author

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FIGURE 4

ENERGY AND TRANSPORT

COMPÁRATIVE DATA

ITEM	J. VELITCHKOVITCH ALAF Bulletin. June 1979 Data relating to France	M. LOSADA ALAF Journal January 1979 Data relating to Spain
Units and equivalences used	I Tep = 1.5 Tec I l. gasoil = 3.4 Kwh I l. petrol = 3.1 Kwh	I Tep = 1.4 Tec I l. liquid fuel = 3.0 Kwh
List of specific consumption:		
- Road: FC (General)	2.5 : 1	2.3 : 1
- Road: FC (Freight)	3.3 : 1	1.9 : 1
- Road: FC (Passengers)	--	2.8 : 1
- Air: FC (Passengers)	6.0 : 1	7.5 : 1
- Navigable waterway: FC (Freight)	1.7 : 1	1.0 : 1

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systems are entirely dependent on oil, whereas the subway is wholly independent and the railway is partially independent of petroleum derivatives.

For example, in 1979 RENFE consumed 1.05 billion Kwh and 170,000 Tns of oil products. Its total dependence is 51%, which is certainly a large figure, but one which is reassuring with respect to the presumable crisis in the supply of oil products. If the current railway traffic were to be carried by other modes, Spain would need to increase imports of liquid fuel by 0.4 million Tns annually (the equivalent of 7,000 barrels per day).

Adaptability to the Productive Structure

No aspect of energy use should be overlooked. For example, a special characteristic of the railway is high use at night. This fact makes the railway an ideal user of electricity in the off-peak hours when at marginal costs, any additional requirement can be met. In Spain, almost 60% of railway traffic is carried at night, when only 40% of Spain's electricity is consumed. For the producers of energy in Spain, the cost of off-peak production is less than half the average cost (1.0 pesetas/Kwh of marginal costs compared to 2.4 pesetas/Kwh average cost).

Versatility

Versatility measures the capacity of different modes of transport to take advantage of different fuels or forms of energy. The railway again is in a dominant position now, not because of its real capacity to take advantage of a greater number of different fuels (coal, oil, and gas) directly, but because of the possibility that it can operate by means of electric traction thus permitting it in the final analysis to be a potential user of any form of energy that is exploited today or in the future. This includes the primary forms of energy currently usable in the production of electricity (hydroelectric, thermal coal, nuclear fuel, and nuclear fission plants), and those that may be exploited in the future (fusion, solar, geothermal, biomass, etc.).

The versatility of the railway, therefore, represents a factor of security against possible difficulties with oil supplies and also allows a high degree of responsible optimism since new forms of electric energy can make it possible to reduce even further the railroad's degree of energy dependence on petroleum derivatives. In the final analysis the existence of a railway that is wholly independent of liquid fuel is perfectly conceivable.

The recent plans for railway electrification, which within the scope of the UIC have made it possible in Europe to increase traffic under catenaries up to 62% of the total, may enable railways to shake off the oil yoke from which it would be difficult for other modes to extract themselves.

Economy

All that has been said has obvious economic implications. Three economic considerations which should be emphasized in intermodal comparisons are:

1. The difference in energy costs should be considered in relation to the cost of substituting one transportation mode for another with a different efficiency index. For example, if Spanish railway traffic had to be borne by other modes, users would have to bear a price supplement likely to increase which, in 1979 monetary values, would be of the order of 1.16 pesetas per U.K.

2. Another consideration is the energy balance of payments accrued in foreign currency. In the case of Spain, actual railway traffic represents an annual economy in foreign currency of 4 billion pesetas (1979) when compared to projected costs for other modes.

3. The differences in the effect of repeated oil price increases on different transportation modes should be considered (since the weight of the energy component in the final price is extraordinarily diverse). To be specific, during 1979, the part of the price paid by the user that was chargeable to the energy consumed represented 7%, 25%, and 33% in the railway, the road, and air transport, respectively.

When preparing the price indices, the majority of countries isolate costs for different transport modes. This makes it possible to calculate the direct impact of oil prices on the corresponding annual indices of inflation. For example, based on an annual increase in the price of oil, it was found that of 37% (the cumulative annual rate for the past 8 years) and in accordance with the unitary components of the Spanish shopping basket, the effects produced by each of the modes--railway, road, air--would be 0.02%, 1.70%, and 0.08% per annum, respectively. In general, inflation indices directly derived from price increases for each mode, as a consequence of the rise in price for liquid fuels, in Spain are 1, 4, and 85, respectively for the railway, air, and road.

Conclusion

This paper has exposed a series of indicators that can help to clear up doubts when we compare energy-efficiency among various modes of transportation. Of course, transport planning and regulation cannot and should not be done by considering the energy question exclusively. But the continuing crisis which will certainly become worse, together with the dependence of the transport sector on liquid fuel, requires that energy costs and rates of consumption be studied and analyzed with greater precision.

This analysis can be systematized by studying the behavior of each mode with respect to the following table of dynamic indicators:

A. Quantitative Indicators

- Gross performance - Specific consumption and indices of efficiency
- Percentages of traffic and energy
- Differential energy balance with respect to the hypothesis of intermodal substitution of traffic

B. Qualitative Indicators

- Energy independence in relation to petroleum derivatives
- Differential energy balance in relation to the consumption of liquid fuels with respect to the hypothesis of intermodal substitution of traffic
- Capacity of marginal use of the existing electrical production
- Versatility in relation to the use of different sources of energy

C. Economic Indicators

- Differential economic balance of the energy bill:

    - In foreign currency
    - In prices paid by the user

- Inflationary pressures

The application of the table to the case of Spain and many other countries Spain shows the strong energy position of the railway. This in part justifies the frequency of data that speaks of its renaissance in all parts of the world.

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ENERGY SAVING IN TRANSPORTATION: THE FRENCH POLICY

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The oil crisis of 1979 has slowed the acceleration of energy consumption in transportation. From 1965 through 1973, the consumption of oil products by transportation in France increased at the mean rate of 8% per year. From 1969 through 1973, the average annual rate of increase exceeded 9%.

During the two years that followed the oil crisis (1974 and 1975), energy consumption was broadly stagnant in France. Since 1976 the rate of consumption has increased again, but at the rates of only 2.6% in 1977, 2.4% in 1978, 3% in 1979, and 1.8% in 1980.

The transportation sector in France requires 20% of the total energy (36 million T.E.P. from a total of 188 million T.E.P.). However, the rate is greater if we consider oil products only (34.5 million T.E.P. from a total of 102 million T.E.P. in 1980).

In fact, the transport sector in France is heavily dependent on oil. Oil represents more than 95% of the energy consumed in transportation. Electricity is used more and more in railways and metropolitan transport, but remains a small share of the total. Coal has not been used in the transport sector since 1970.

On September 24, 1974, the French Government created the "Agency For Energy Economics" as a public establishment under the Department of Industry and Energy. The Agency proposes to the French Government the decisions that are to be taken in order to save energy and organizes the application of these decisions. In this field, actions are founded chiefly on four points:

1. Legislation and Regulation,
2. Advertisement,
3. Acknowledgement, and
4. Financial Incentive.

The aim is to save 60 million T.E.P. in 1990, compared to a baseline projection prior to the oil crisis of 1973. A savings of this magnitude would be comparable to the production of energy anticipated from the French Electronuclear Program, which will provide (73 million T.E.P. in 1990.

In transportation, the objective is 11 million TEP saved in 1990. Each year from 1981 through 1990, an additional 0.6 million TEP must be saved. The following table provides a sense of scale for these savings: the transportation sector saved 1.5 million MTEP in 1975, 1.5 MTEP in 1976, 2 MTEP in 1977, 2.5 MTEP in 1978, 3.1 MTEP in 1979, and 3.9 MTEP in 1980.

	ECONOMIES RESULTING FROM INVESTMENTS IN THE TRANSPORTATION BRANCH (UNTIL 1990 IN TEP)		
		MODIFICATIONS ON	
	TOTAL	NEW PRODUCTS	EXISTING PRODUCTS
CAR AND COMMERCIAL VANS	3	1.5	1.5
TRUCKS (GOODS TRANSPORTATION)	1.5	0.75	0.75
OTHER MEANS OF TRANSPORTATION	1.5	-	-
TOTAL	6	-	-

What has Already Been Done in Energy: State of the Art in 1981

Helping Innovation

The Agency for Energy Economics provides financial help to the French car-building industry in order to promote new techniques in conception, maintenance, and utilization of vehicles. The synthesis prototypes, called EVE (Renault) and VERA (Peugeot), have received exceptionally high financial help from the Agency for Energy Economics.

Helping Demonstration

In order to promote the full utilization of new products, the Agency subsidizes the buyer. The Agency supports the cost of a technical gauge in order to test the energy efficiency of those new products.

Helping Investments

To reach the large public of consumers, the Agency uses the language of advertisers on radio, television, and in the newspapers. The leading slogan is: "A new way of saving your oil consumption when you drive your car: you can learn easily the rules of economic car driving." The Agency also helps in the commercial promotion of some equipment for cars or trucks that can improve fuel economy.

The auto industry in France now attempts to meet specific objectives for fuel efficiency in new cars. The target set for new cars in 1985 is 7.3 L/100 km (32 mpg), and 6 L/100 km (39 mpg) in 1990. Fuel consumption for all new cars sold in France is published twice each year in daily newspapers. This provides consumers with important information on actual and estimated fuel consumption of every type of motor car. This may help a buyer decide on which car to purchase if the buyer is concerned with fuel consumption.

What Shall Be Done In The Coming Years?

Private Cars

The fuel economy objective for new cars bought in 1979 was 8.3 L/100 km (28 mpg). This is to be reduced to 6 L/100 km (39 1/4 mpg) in 1990. The synthesis prototypes (EVE and VERA) consume 25% less fuel than the current new car fleets. This saving results primarily from aerodynamic optimization and weight reduction. Those programs will be continued in order to give EVE and VERA the Appriated engine and the kinetic transmission. This will reduce auto fuel consumption by an additional 25%.

The main auto makers are undertaking a vast program of conception of the mass-produced car for 1990. Those cars (Renault's Vesta and Peugeot's Eco 2000) will require only half the fuel consumed by the lower class vehicles available on the French market this year. This saving is the product of weight reduction, new engine design, kinetic transmission, and energy recuperation.

To address the existing auto fleet, emphasis will be placed on the development of consumption indicators for the car driver, and the promotion of efficient lubricators, aerodynamic kits, and carburetor economizers. To address urban auto traffic, the Agency will provide financial assistance to local collectives in order to study the energy efficiency of traffic light optimization systems.

Trucks

A new generation of trucks will reduce the fuel consumption of trucks by 30%. The prototype (VIRAGES) will be available in 1985. To improve fuel efficiency in the existing truck fleet, the following actions will be undertaken:

- aerodynamic improvements (cabin deflectors),
- promoting new products (improved oil lubricators, and systems that indicate economic driving to the driver), and
- efforts to improve driver behavior with general rules on economic driving.

New buses will have improved performance due to specifically adapted engines, optimized auxiliary systems, and a hybrid kinetic transmissions.

Conclusions

All of these projects will address energy savings to improve the use of energy from currently available sources without substituting other sources of energy. In the very near future, the public authorities in France will help to promote non-petroleum vehicular systems, electric domestic vehicles, alcohol petroleum mixtures available for motor cars (called carburols), and wood gazogenous engines. These non-petrol systems cannot be developed for or at this symposium. This technology will be developed in the next few years, and we shall have a better knowledge of it in the near future.

ENERGY CONSERVATION IN TRANSPORTATION: LAND USE PLANNING AND MANAGEMENT

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Abstract

This paper considers that if energy conservative land use and transportation planning and management is to be achieved, energy must be introduced into the planning process by setting oil-based transport fuel at a price level such that long-run marginal social cost (LRMSC) is equal to long-run marginal social revenue (LRMSR), a necessary condition for correct economic use of transport energy resources.

Furthermore, the paper proves that drivers are currently misperceiving the cost of running their vehicle. In the case of fuel prices, drivers perceive only one-third of real costs. This misperception must be corrected in order to conserve resources.

It is suggested that an idealized land use and transport plan can be developed on the basis of setting oil-based transport energy at a price level that LRMSC = LRMSR and correcting drivers' misperception. Research is suggested to evaluate both these latter values. A meter is proposed as a possible measure to correct motorists' misperception of car-running cost. If proved effective in practical testing, all vehicles should be required to have such devices.

Idealized land use and transport solutions will be helpful in selecting land use and transport systems that can operate in an energy conservative way. This idealized solution will also act as an objective measure against which existing land use plans and transportation system performance can be measured and appropriate action taken to correct misuse.

Detailed practical measures are suggested in both land use and transportation to move present imperfect energy use toward a more efficient use that will have been identified in the idealized analysis.

Forward

This paper synthesizes views presented over the past five years to the European Economic Commission (EEC), Energy Sub-Group C, which is the advisory body on energy conservation in road transport, and also to the Institute of Engineers of Ireland.[1] The paper also includes findings of the NATO Institute for Advanced Studies Symposium on Energy Conservative Urban Form held in 1979 at the University of Louvain-La-Neueve, Belgium.

The EEC Energy Sub-Group C has concluded that there will be an energy crisis in the transport sector and that difficulties will be encountered in overcoming the crisis. Since the forecasts seem to be accepted by knowledgeable persons, the authors have accepted these forecasts without further questioning. Consequently, we have not considered it necessary to elaborate further though we do recognize that this prognosis is important to the thesis advanced in the paper. In this situation it is necessary for those responsible for land use and transportation plans and for ongoing transportation management to design and operate the systems so that energy is properly conserved. Conservation is best achieved in free market economies through the operation of market forces. Unfortunately, market forces can become distorted.

The authors have therefore thought it worthwhile to try to determine the type and size of the distorting forces in the land use and transport sectors focusing on their elimination in whole or in part and to see what research activities should be undertaken to achieve these ends. An understanding of these distorting forces will permit the selection of land use and transport systems that will operate at a correct economic level, that is, making proper allowance for energy scarcity and allowing transportation management measures to operate to a well-defined objective.

We have not endeavored to be comprehensive but have merely outlined the nature and character of the thrust required. We have little doubt that further modifications and adjustments to the proposals will be needed.

Introduction

Historically, land use planning has been determined without detailed reference to transportation planning. Rather, transportation planning has been an outcome of predetermined land uses. In more recent times, the two processes have been seen as interactive. Modern computer techniques and behavioral models permit analysis of the interaction between such systems. The potential, therefore, exists to determine optimal plans given any set of resource considerations. However, while this interactive analysis is feasible in practice, such plans have not been optimized with a comprehensive set of resource constraints in which energy is included in an appropriate way.

The necessity to control land use developed for reasons unassociated with energy conservation--in fact, the availability of cheap transport was one of the factors that led to the extensive urbanization of the 20th century. Land use planners saw as their objective the orderly development of this urbanization but did not necessarily see their brief extending to the proper use of transport resources. One can argue that this approach is perfectly correct in that market forces should adequately cater for the use of transport. Thus, those who can afford private transport will do so, and others will resort to public transport or relocate close to workplace. Unfortunately, market forces achieved the objective of proper use of transport resources due to market distortions. These distortions consist of the market's inability to reflect the true resource of energy and the failure of market prices to be fully incorporated in consumers' decisions.

Had energy been priced appropriately (that is, at its true resource cost) from an early date, and if consumers had perceived these costs accurately, a totally different urban scene would now apply. Its exact form cannot now be known, though urban sprawl would not be such an extensive feature of it.

How then should the problem of energy conservation in transportation and land use planning be approached? In attempting a rationale, we must recognize that an optimal solution is unlikely, given the level of resource allocation which has already been made and which will still exist over the next 20 years. However, if an optimal "idealized" solution can be identified, then various practical measures can be taken to move an imperfect situation toward better resource use. Such an optimal solution will exist only when all forms of energy are priced at their true resource costs and consumers perceive these costs fully.

These idealized solutions can give guidance to the selection of land uses and associated transportation systems when energy is given its rightful place in the land use and transportation planning process. They provide guidelines against which energy transportation systems can be gauged. Thus, in practice, the day-to-day use of transportation facilities will diverge considerably from the levels indicated in the idealized solution. Transportation management then must adopt policies and practices which will ensure that the use of the facilities tend toward the usage identified in the idealized solution.

The purpose of this paper is to establish that the distortions mentioned above exist, to estimate their absolute value, and to consider how well-known traffic management policies help achieve transportation facilities free of such distortions. The paper then outlines management strategies for achieving a more correct use of energy and a more correct perception of its true value. The paper first considers a relevant methodology to these ends.

Planning for Energy Conservation in Land Use and Transportation Systems

As indicated above, an idealized system of transportation and land use would consider true energy costs. The first point to consider in this connection is the true resource cost of energy. While the concept of true energy resource costs is relevant to all forms of energy, for land use, transportation planning and management, we can limit consideration to oil-based energy or to oil-based automotive fuels and their alternatives, as these fuels dominate in transportation.

The important question is to determine the correct level of use for such oil-based transport fuels. This raises considerations of the long-term trend in the cost of such fuels and the real source cost of this type of energy.

Long-Term Trend in the Cost of Oil Based Transport Fuels

The pattern of movement in long-term costs throughout the 1960s and early 1970s was essentially downward as the real price of such energy was maintained while personal disposable incomes increased. This resulted in continuous growth in car ownership and a continued expansion of the city into suburban and then exurban sprawl.

Since 1973 the movement in long-term costs has been less clear, with oil prices initially rising in real terms, but then faltering as recession and its industrial slow down reduced overall energy demands. However, it is possible to interpret these adjustments as providing the first insights into a major change in the pattern of long-term costs that will arise in the next 10 or 15 years. Most studies show the expansion in world population and the likely return to economic growth patterns will reassent the demand for energy, but supply will continue to be constrained, so energy prices will rise in real terms. The rise in prices for oil-based energy that is suitable for transport will be considerable, possibly up to a 200% increase in real terms. Such an increase must represent a major dislocation in the economic system which in turn will affect both land use and transport patterns and activity.

Real Resource Cost of Oil-Based Transport Fuels

The current conventional wisdom of transportation planning is that the resource cost of energy may be calculated as the market price of energy minus any national taxation. Unfortunately, this conventional wisdom is misleading in economic terms as the resource cost of energy should be set at the price at which long-run marginal social cost equals long-run marginal social revenue benefit. However, such an optimum resource use requires full knowledge of both revenue and cost changes over time as well as the exact level of externalities that will exist. This is obviously far removed from the existing international energy market, which clearly has neither perfect knowledge about costs or revenues, but equally little notice (or only necessary notice) is taken of externalities in the complicated oligopolistic (few producers) and monopolistic (few purchasers) competition that exists. In this situation a resource misallocation is clearly the likely result.

Furthermore, a transport is almost totally dependent on petroleum as an energy source. Since 1975, we have become increasingly aware that petroleum is in relatively short supply and is a depleting resource. Ultimately, the price of petroleum products may be expected to rise to the level of alternative automotive fuels. However, we now have no proper estimate for the costs of these alternative fuels in the quality and quantity required. Costs for alternative fuel may be in excess of two times the present petroleum costs.[2,3]

Due to technological advances, these price levels may not be attained in practice. Nevertheless, the resource price of future automotive fuels (LRMSC = LRMSR) must have a very substantial rise in accordance with the above engineering assessments of the cost of production of alternative fuels. (Long-Run Marginal Social Cost = Long-Run Marginal Social Revenue.)

Transport Implications

Existing land use and transportation plans give little consideration to the amount of energy required in the operation of the plan. The increasing segregation of land uses that has been the main feature of 20th century land use development has been a product of inexpensive transport based on inexpensive oil-based fuels. Changes, especially in the availability and price of oil-based automotive fuels, must inevitably mean a change to a more integrated land use system. A more integrated land use system will make it possible to reduce the volume of discretionary trip making, and to more easily service it by the most energy-efficient means of private and public transport.

The correct choice of land use can only be made when the price of petroleum (and alternative fuels) is assumed to be at a level where LRMSC is equal to LRMSR during the time considered in the planning process. The value for these prices is a matter for research.

Perception of Motoring Costs

The second factor is the question of the consumer's perception of prices. Motorists misperceive car-running costs substantially.[4]

The perception of motor car-running costs has been a source of concern since the earliest attempts to analyze transport problems. This concern was intensified in the late 1960s and early 1970s when in Europe and America the "plea to save the city" focused transport research on individual behavior and the factors which affected it.

Behavioral research concluded that most of the characteristics which affect travel behavior are well understood and perceived quite accurately by individuals; car-running costs were a major exception. Initially, transport planners and economists assumed that individuals would base decisions on the average cost of using a car; the marginal costs of motoring better reflected individuals' decisions. However, ensuing research included that motorists probably do not perceive even the marginal costs in travel decisions, but a figure approaching only 20-30% of the marginal cost.

If this recent result is correct, motorists only perceive a part of the total costs of motoring and they make incorrect travel decisions, that is, too great a use of the car. In catering for these decisions, society misallocates resources in terms of economic equilibrium. Research regarding the impact of this misperception and misallocation of resources suggests the elasticity of demand with respect to petrol price could be made two or three times more sensitive if the misperception did not occur.

However, in practice, the reaction of improved perception is likely to be much less due to a range of considerations: the difficulty of changing current social, cultural, and economic factors that indirectly affect travel behavior; the need to make fundamental adjustments in life style, home location, and leisure activities; and the level of business use made of the car and subsidizing of personal use that often results from such arrangements. We estimate that the initial effect of improving perception would be to create a change of perhaps 5% to 15% in overall demand, an adjustment equal in the short run to a 50-150% increase in fuel prices.

Correcting the misperceptions of motorists would also increase the effect of any future price rises. The level of increased reaction will be equal to the level of increased perception induced by correcting the misperception. For example, a rise of petrol prices of 60% is currently viewed by motorists as only an increase of 20%, since two-thirds of the price rise is misperceived. Improved motorists' perception will increase the size of price rise perceived by the motorists. Assuming that motorists correct misperceptions completely, the 60% increase in price is perceived as a full 60% increase. Assuming a short-term elasticity of -0.1, the increase in responsiveness that would result from the increased perception would be equal to the difference of the following equations:

(a) Misperceived price increase
$20 \times 0.1 = 2.0\%$ fall in demand

(b) Corrected perception price increase
$60 \times 0.1 = 6.0\%$ fall in demand

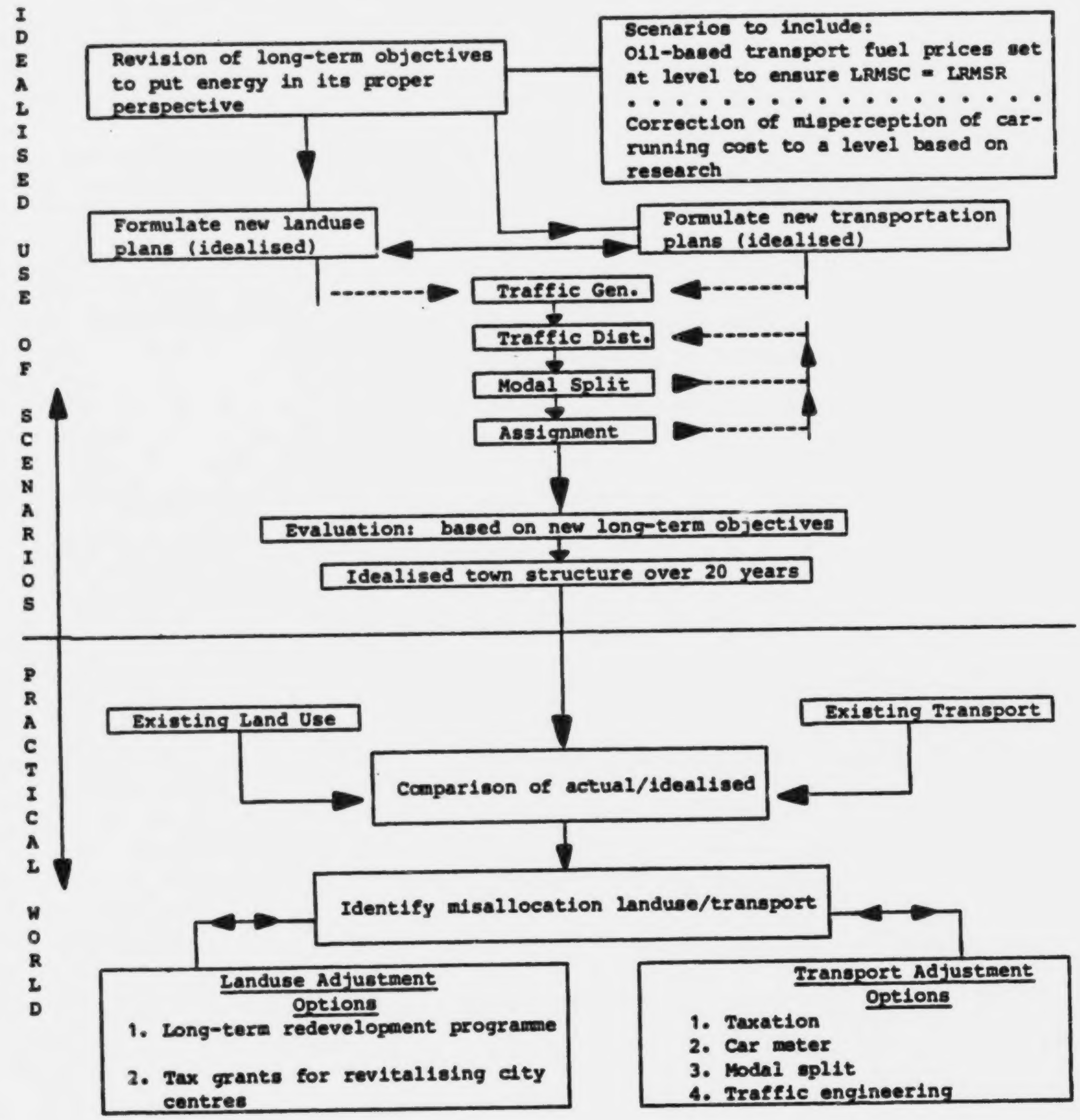
(a - b) = an additional fall in demand of 4%

In this way, the effect of correcting the misperception would continue to operate through the price system as a continuing mark-up on price increases. The savings associated with the correction in the short and long run are therefore substantial and represent a major adjustment to transport demand, particularly if associated with the considerable price increases that may be expected over the next 20 years. Such adjustments are fundamental to the establishment of economic equilibrium and as such represent no more and no less than what is appropriate for the correct use of resources.

Revised Planning Method

Given that the assumptions concerning the future availability of cheap energy are reversed, that the principles of long-run marginal social costs are adopted for energy pricing, and that motorists can be made to perceive the true cost of running their vehicles, an idealized analysis can carry out the procedures outlined in the following flow chart. Initially, objectives are set both for existing and proposed land use that requires the introduction of energy costs at a price such that LRMSC equals LRMSR: motorists are presumed

FLOW CHART - REVISED METHOD
TRANSPORTATION AND LAND USE PLANNING AND MANAGEMENT


IDEALISED USE OF SCENARIOS
Revision of long-term objectives to put energy in its proper perspective
Scenarios to include:
Oil-based transport fuel prices set at level to ensure LRMSC = LRMSR
Correction of misperception of car-running cost to a level based on research
Formulate new landuse plans (idealised)
Formulate new transportation plans (idealised)
Traffic Gen.
Traffic Dist.
Modal Split
Assignment
Evaluation: based on new long-term objectives
Idealised town structure over 20 years
PRACTICAL WORLD
Existing Land Use
Existing Transport
Comparison of actual/idealised
Identify misallocation landuse/transport
Landuse Adjustment Options
1. Long-term redevelopment programme
2. Tax grants for revitalising city centres
Transport Adjustment Options
1. Taxation
2. Car meter
3. Modal split
4. Traffic engineering

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to perceive car-running cost to a greater extent than now applies. The exact figure that should be adopted for the correction of misperception is a matter for evaluation by research as is developed below in a discussion of the use of a car price meter.

A planning and land use analysis is then carried through using techniques normal to such analysis and to a planning horizon of approximately 20 years ahead. Idealized land use and transport systems will be developed from this analysis and these idealized designs can then be compared with the actual situation. Thereby, misallocation of resources can be identified and adjustments attempted to a well-defined objective level as follows:

Land Use - by long-term redevelopment and possibly by revitalizing urban centers using government subsidies.

Transportation - by taxation management,
by correction of misperception of car-running cost measures.
by modal split management, and
by traffic engineering measures.

Adjusting Land Use and Transportation Systems Towards Correct Energy Scenarios

Land Use Measures

Land use patterns develop in a slow, continuous process. Nevertheless, a real opportunity exists to revise plans and to change the overall land use pattern to make it more energy conservative and more energy efficient.

Short-Term Measures

In order to promote and revitalize the urban environment, which will clearly take on a new and increasingly important role as real energy prices rise, consideration should be given to ideas such as those promoted by Jane Jacobs and other urban planners.[5] Grants and guarantees should encourage the redevelopment and rehabilitation of central urban areas. In particular, low-cost mortgages could play a role in such redevelopment programs.

Long-Term Measures

Most important, however, will be the land use pattern as determined from the idealized analysis--this will have indicated a necessary trend in redevelopment. Desired land uses, therefore, can be selected and controlled in accordance with these guidelines. The underlying assumption will be that energy-conservative transportation systems can be associated with such redevelopments. The idealized analysis will have shown such systems to be feasible, but transportation measures in fact will be required to make such an idealized system realistic in practice.

Transportation Measures

Taxation

The natural mechanism with which the government of a mixed economy can manage a resource allocation (or use) problem is taxation and subsidy. In applying either taxation or subsidy the government can direct its attention to both producers and consumers. Transport has two products of concern: vehicles and fuels. A government may act upon both or either.

Governments have regulated the production and consumption of vehicles in the past with other measures of purchase and ownership taxation. These measures have had little direction, except that sometimes they have been made progressive by raising more money from larger vehicles. The option open to government is to introduce a more progressive taxation policy that uses incentives to encourage the production and consumption of more efficient cars--smaller and less powerful.

Effect on Car Ownership

Little is known of the exact effect of purchase and ownership taxes of production incentives. However, evidence that is available suggests that very large tax changes or incentives are required to affect major changes in the pattern of car ownership and types of cars bought. American studies reveal that shifts in car size are possible, but that shifts can be limited by a stable component in the demand for different types of vehicles that would be difficult to influence by price changes. Furthermore, such a policy could only have an impact in the long run since the lead time on fleet replacement is about 10 years.

Effect on Fuel Use

Considerable effort has been made recently to identify the extent of price on demand for fuel. A number of points may be made. First, "elasticity of demand" is inelastic. Both now and in the future we can expect the demand for fuel to be insensitive to price increases as noted already. The short-run elasticity is about -0.1 to 0.2,[7,8,9] so that each 10% increase in price gives a reduction in demand of almost 2%, while the long-run elasticity is about -0.4 to -0.5, which means that even in the long-run a 10% price increase will give only a 4% to 5% reduction in demand.

Second, motorists' perception of car-running costs is very poor.[10] When making travel decisions, motorists consider only 20% to 30% of the real marginal cost of running a car. Since, in economic terms, the correct use of resources only occurs when the long-term marginal social cost is correctly perceived, the price mechanism is distorted, and motorists are considerably underrating the resources they are using.[11,12] Consequently, a very real waste of energy resources is occurring.

The combination of low elasticity and poor perception creates the difficulty in persuading motorists through fuel taxation to reduce demand for petrol for travel. In order to be politically acceptable, therefore, fuel taxation as an energy conservation measure would have to be implemented through a long-term program of small steadily rising real tax increases, while some attempt must also be made to overcome the misconception of car-running costs. These views are largely substantiated in the Interim Report of the Special Group on the Influence of Taxation on Car Fuel Consumption, EEC Sub-Group C.

Car-Running Cost Meter

To overcome the misperception of car-running costs, motorists must have better information on the true cost of running their cars. One possibility is to install price meters in their vehicles. Experience of meters in electricity and telephone use shows that a considerable reduction in demand can be obtained by showing rate of cost use. In the case of telephones this has been estimated to be as high as 35%.[13]

The behavior of individuals toward tax meters suggests that the reduction in consumption might be as high as 20% in cars.[14] We suggest that meters should indicate both the marginal and average cost of journeys as they are undertaken, and they should differentiate between different speeds, so that, for example, a motorist could compare his costs when driving at 50 miles per hour rather than at 60 miles per hour. While marginal costs would be determined from information on miles per gallon, speed and maintenance costs and average costs could be obtained from mileage expectations, purchase and insurance costs. In this way, motorists' misperception of car-running costs might be overcome and a better use of resources obtained.

A successful metering device will produce numerous benefits. It will reduce the fuel consumed by the private car by encouraging more rational travel decisions and better planned trips. This would include more effective use of public transport, particularly for the work trip. However, before such a device can be mandated, its effectiveness and safety need to be investigated by practical testing.

Transportation Management

Modal Split Changes

If the existing transport plans and predictions are based on a misperception of the real value of oil resources, then a real effort to correct the misconception will be an important step in energy conservation. Given the insensitivity of motorists to fuel prices, other measures must be sought and, as suggested above, the price meter might prove effective. Additionally, transport management options, particularly opportunities associated with modal split can be exploited. Modal split changes designed either to encourage a greater use of the more energy-efficient public transport or discourage road traffic provide significant energy savings in urban areas. Modal split changes can be induced by either restraint or market measures.[15,16] Direct physical restraint, such as parking measures, could contribute to reducing road traffic and encouraging public transport use. However, a combination of market measures properly implemented could also produce major modal split changes. For example, a whole series of modal split studies in Britain and Ireland reveal that for the work journey in urban areas the impact of various modal split market measures would be of the order given in Table 1.

TABLE 1

EFFECT OF DIFFERENT TRANSPORT MANAGEMENT POLICIES ON CAR USE

Policy Change	Percent Reduction in Car Use for the Work Journey
1. Reduce bus waiting time by 5 minutes.	5%
2. Reduce bus walking time by 5 minutes.	5%
3. Reduce bus in-vehicle time by 10 minutes.	5%
4. Reduce bus fares by 5 percent (1971 prices).	5%
5. Increase car parking charges by 10 percent (1971 prices).	5%
6. Increase car walking time by 5 minutes	8%

SOURCE: K. Rogers, A. Metcalf, and G. Townsend, "Planning for the Work Journey," LGORU Reading Report C69, 1971.

Traffic Engineering

Relief of road congestion would seem to be an effective way of reducing fuel consumption. However, caution is needed regarding this conclusion. Relief of congestion could encourage distance or high speed, and an energy penalty would be incurred. Furthermore, in the case of road building, we must recognize that the need for roads arises from a motoring demand currently based on the motorists' misperception of car-running costs and relatively low projected fuel prices, as explained above. Consequently, social cost benefit evaluation of road requirements must have cognizance of the effect on traffic of the increasing fuel prices that can be expected in the future, and the improvement in the perception of car-running costs that must be sought to achieve a proper use of resources.

Therefore, social cost-benefit evaluations of road requirements and the effects on traffic from future increases in fuel prices must be considered.

Conclusions

The thesis advanced in this paper is that present urban form and transportation systems are highly unlikely to be energy conservative and certainly cannot represent correct economic efficiency for a world short of energy. These conclusions are based on the fact that the 20th century urbanization was founded on the false premise of the continued availability of cheap energy. Modern economic theory, however, shows that correct economic use of resources can only occur through the principle of long-run marginal social cost pricing. The authors believe that energy is currently priced too cheaply. Oil-based transport fuel could be under priced by a factor greater than two, as determined by the cost of alternative fuels. Research is obviously required to evaluate the timing and value of the long-run marginal social costs for energy and transport fuels.

If a market situation prevailed in which LRMSC = LRMSR for both petroleum products and transport services, then consumers would reduce their demand for oil (and energy) as prices rose, and producers would increase their supply. Consequently, smooth transition to a situation of high petroleum prices and alternative transport fuels would ensue. However, in reality, the oil political intervention could lead to price distortion. We have only to look at the huge variations in prices over the past eight years to appreciate this point.

Even if the international oil market were structured perfectly, distortions would arise because of the nature of the transport market. First, it cannot be assumed that transport consumers or producers have perfect knowledge and are in a position to anticipate and prepare for the future level of transport energy prices. Indeed, this paper argues that at least one category of transport users (car drivers) underestimate and misperceive their expenditures on fuels. Second, because transport demand is related to land uses that are slow to change, and because transport investments are long-lived and often have substantial lead times, the consumers' ability to respond rapidly to price signals is severely curtailed.

In these circumstances, everyone involved in energy conservation or land use and transportation planning and management must examine the most effective steps that can be taken to achieve energy conservation, but only to a level that represents the correct economic use of energy resources.

The essential first step is a theoretical land use and transportation analysis which assumes both long-run marginal social cost principles and that motorists will have a better appreciation of motor car-running costs. This theoretical analysis will show the correct trend for urban redevelopment. Such redevelopments should be controlled in accordance with these pointers, using subsidies, if necessary, to revitalize urban centers. Energy-conservative transport systems will also emerge from the theoretical analysis and provide objective measures for transport planning and management.

The major difficulty requiring attention is misperception of motoring costs by drivers. The estimated magnitude of this misperception, on the order of one-third of total costs (that is, two-thirds ignored), means that considerable misuse of transport resources will continue to occur unless remedial steps are taken. Price increases in transport fuel can only marginally assist here. Other steps, such as the mandatory requirement of a car-running cost meter for each car, must be considered. The research implications are obvious.

In the meantime, one option open to governments would be to use taxation policy to:

1. ensure that the real price of transport fuel is not allowed to fluctuate wildly because of the vagaries of the international oil market; and

2. raise transport energy prices so that the transport market will be encouraged to adjust to the high energy-cost future that will be associated with the use of alternative fuels.

These policies would prevent crises in the transport market and reduce both current and future energy import bills. The major issues requiring research are: what constraints impinge on the use of taxation as a policy instrument; what type of tax structure is needed to ensure the necessary restructuring of the transport market.

More traditional transportation management techniques may also be used to achieve the objectives as set by the theoretical analysis.

Acknowledgements

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AUSTRALIAN DOMESTIC FREIGHT TRANSPORT - THE SYSTEM ENERGY PERFORMANCE OF COMPETING MODES

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Abstract

The paper is based on work being undertaken in the Bureau of Transport Economics to establish a sound basis for comparison between the main freight modes.

There is a brief discussion of the appropriate level of task specification and disaggregation to employ in analysing modal energy use data. Details of the actual study undertaken are then described, covering collection of data for a selection of trunk routes in Australia. The characteristics of the data are examined and analysed to develop a presentation of modal characteristics which can be used as performance indicators for each mode for varying operating conditions. Particular attention is paid to railway systems and the impact of very widely varying system parameters on their performance.

It is found that railways have the potential in their present form to be significantly more energy efficient than either road or sea transport in the general freight role for heavily utilised main lines, although it is not possible to reliably determine how fully that potential is realised.

Introduction

The work reported in this paper was undertaken because of a concern that sweeping statements about the desirability of diverting traffic from one mode to another in order to save fuel were being made on the basis of overall energy intensiveness figures which can be misleading if applied in any particular case. Thus, the paper is concerned with determining what constitutes a proper basis for examining and comparing the energy performance of alternative modes.

The paper attempts to clarify the issue by examining, for selected routes, the energy consumption characteristics of the three main freight modes (road, rail and sea) when undertaking comparable tasks. This appears to be the only valid basis for comparisons of energy efficiency--if such comparisons are to be made.

The method of data collection differed between modes. In the case of sea transport actual voyage data for a number of voyages of one typical ship were used. Road data were obtained via a questionnaire sent out to selected truck operators and, as for shipping, was actual journey data. In the case of rail the information was obtained from the various government railway authorities and was a mixture of actual and simulated data.

Task Specification

Even though it is recognised that the use of modal aggregate data is unsuitable for specific task comparisons, the choice of the appropriate level of disaggregation to apply raises problems of principle quite apart from the practical question of availability of data. For example, although it is easily seen that ancillary energy costs such as rail shunting and empty running must be taken into account when determining the performance of the revenue movements, the basis on which they should be allocated is less obvious. The usual measure of output is the tonne-kilometre, but all types of terminal handling costs are physically related more to the tonnes consigned through the terminal than to the tonne-kilometres performed by the system, and the question therefore arises which is the most appropriate basis to use.

Examples abound which demonstrate that the analysis of energy used in freight transport is a problem in which the classic questions of "lumpiness" and "jointness" constantly arise. It rapidly becomes clear that to identify a specific consumption of energy which is physically related to the movement of a specific tonne of freight is an impossible objective except where an entirely homogeneous cargo is moved from a single origin to a single destination. Moreover, in many cases it is not even relevant since, in the case of a mixed freight train, for example, one particular wagon will be moved only when there are a number of other wagons which have to go to the same destination, and each wagon load depends on the existence of all the others (including empty returns) for its movement to occur.

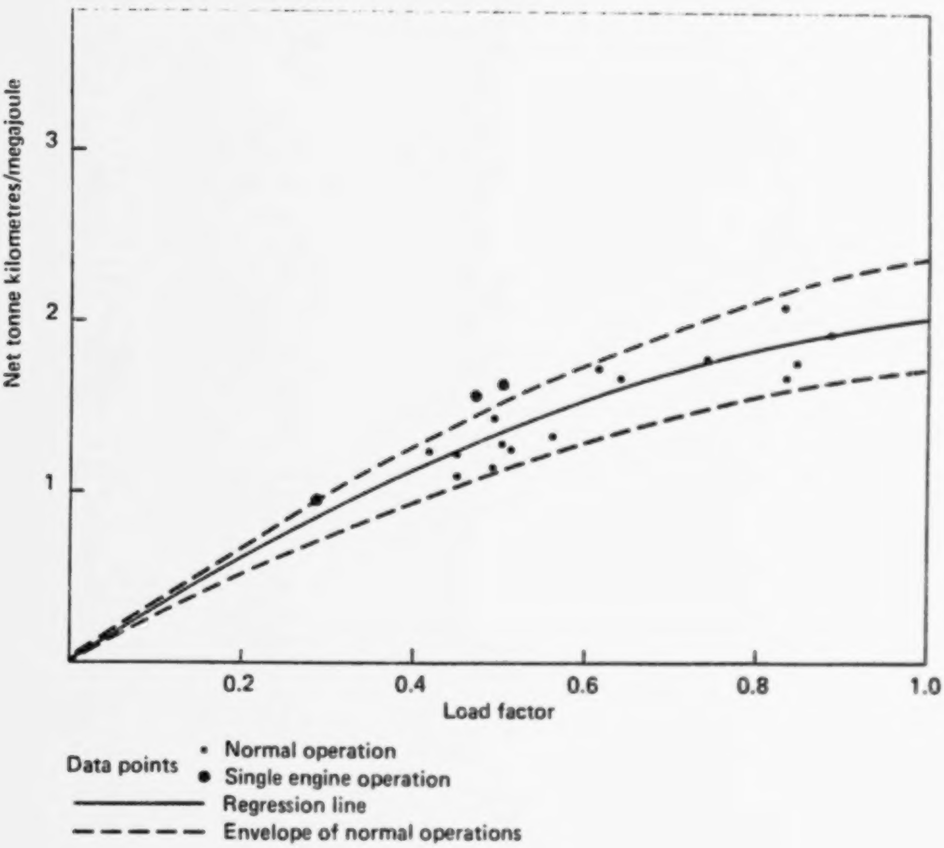
From examination of these issues it is considered that the most rational approach is to regard the total output (measured in tonne-kilometres) or a particular operation or series of similar operations as a joint activity, and to share all the energy costs equally over each unit of output. Given the adoption of this approach, the objective is therefore to try and determine for each mode on each of the selected routes the amount of general freight moved and the amount of fuel consumed in the process. The emphasis on general freight applies mainly to rail and sea modes, where bulk movements have a markedly different character and are therefore excluded. In the case of road transport, freight movements classified as bulk liquid or bulk solid are still effectively single-vehicle loads carried on vehicles of fundamentally similar characteristics to those used for general freight movements, and it is, therefore, not appropriate to try and segregate this class of operation.

Efficiency of Sea Transport

Sea transport, if considered globally, spans a very wide range of ship type, size, and performance. For coastal movements of general freight, however, the smaller container vessel is the appropriate type to consider, and for this purpose the Motor Vessel "Melbourne Trader" is used as the source of data. The "Melbourne Trader" is a 5,000 tonne vehicle deck container vessel with a service speed of 18.4 knots.

Data on fuel consumption and cargo carried were obtained for eighteen separate voyages between east coast ports and provided a satisfactory indication of the ship's characteristics. In Figure 1 this data is plotted together with a regression curve and upper and lower boundaries to the data set.

FIGURE 1
SEA FREIGHT ENERGY EFFICIENCY DIAGRAM
FOR M.V. MELBOURNE TRADER



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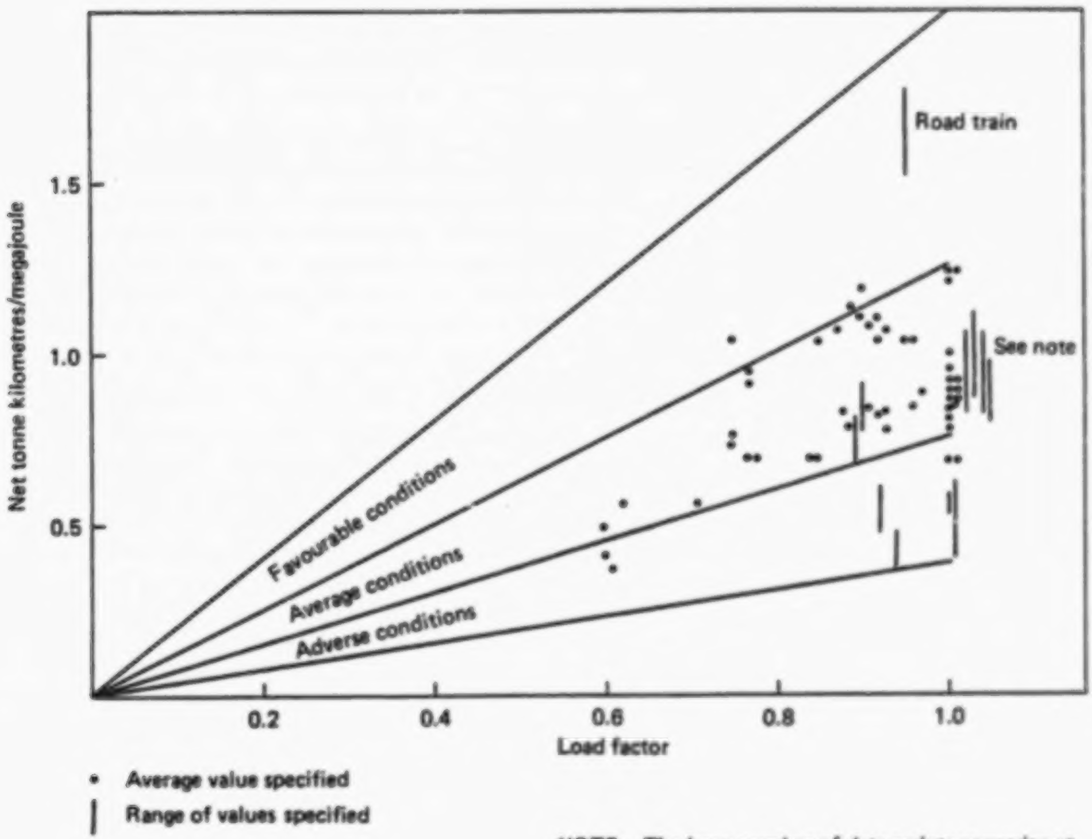
Efficiency of Road Transport

The responses obtained to the questionnaire survey yielded usable data on 47 operator-truck combinations on the various routes being examined. The final results obtained from this data are shown in Figure 2, but there are a number of indications from this data which are noteworthy and which cannot be seen on the diagram. The data obtained supports the view that the efficiency of trucks increases with size. Generally speaking, 36- and 38-tonne semitrailers produced more tonne-kilometres per megajoule than 32-tonne semitrailers, which in turn were better than lighter rigid trucks. The one road train for which data were provided was significantly more efficient than ordinary semitrailers. Many of the returns gave only average fuel consumption data for each route, but those which did provide best and worst figures as well as averages show that for one truck type on one route the variation between best and worst fuel consumption is typically about 20% but can be substantially higher.

FIGURE 2
ROAD FREIGHT ENERGY EFFICIENCY DIAGRAM



NOTE: The large number of data points occurring at load factor = 1.0 have been separated laterally for clarity.

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This variation may be attributed to many factors including differences between individual vehicles of the same type, differences between drivers and variability of weather and traffic conditions en route. What is of particular interest is that this apparently random variation in actual fuel consumption appears to be substantially greater than any systematic variation either between routes or due to changes in loading. In other words, the actual fuel consumption of a truck (in litres per 100 kilometres) does not appear to be much influenced by the route on which it is operating or the amount of load which it is carrying, but it is moderately affected by the way it is driven. It is also clear from the responses that the larger freight-forwarding organisations are able to consolidate loads so that load factors better than 85% are achieved on the great majority of their operations. It appears that smaller operators serving smaller centres are more likely to operate one way at low load factors, though whether this is due to an inherent imbalance in traffic between the large cities and smaller centres or to lack in the organisational ability of small firms to secure adequate return loading is not known.

Efficiency of Rail Transport

The analysis of rail data is considerably more complex than in the case of road data. The characteristics of railways vary considerably from State to State, and the type of data available from each State rail system also varied. These factors compound the problem that a freight train is fundamentally more variable in character than a line-haul truck.

The maximum allowable gross trailing load varies considerably according to the locomotive type, the ruling grade on the route, and the operating schedule to be maintained, and actual trailing loads vary widely up to the allowable limit. The result is the normal main-line freight trains may operate in different parts of Australia with anything from 350 to 1,750 trailing tonnes per locomotive. In addition to this already wide variation, the gross/net ratio varies from different wagons and different types of load, and the type of terrain exerts more influence on the performance of a train than on the performance of a truck. Since it is not easy to define a load factor for rail in the same way as for road or sea, it is better to express the performance of rail in terms of actual tonnes hauled.

Victorian Railways (Vicrail) undertook a series of tests on the 317-kilometre Melbourne-to-Albury standard gauge line during which measurements were taken of the fuel used on each freight train trip during a period of six weeks in 1980. Since only two types of locomotives were used for this traffic, and it was found that there were considerable variations in the gross trailing load of trains during the test, the results provide an indication of the way in which railway fuel consumption characteristics vary with the gross trailing load.

The New South Wales State Rail Authority provided fuel consumption data from computer simulation for the various segments of three main lines--the Main South, North Coast, and Western. Thus for each line, which is simulated for operation at the constant ruling gradient load throughout, the segment-by-segment simulation provides an indication of variability due to terrain.

Actual data on train operation were also obtained for two main lines in Queensland--Brisbane to Toowoomba, which crosses the dividing range, and the coastal route from Brisbane to Rockhampton--and for the Trans Australian Railway from Adelaide to Perth.

The results obtained from Vicrail and Queensland Railways observations and the NSW State Rail Authority simulations permit the preparation of generalised performance curves based on total trailing load.

Although the locomotive performance and fuel consumption is determined by the total trailing load, it is obviously the net load carried which is of interest as a measure of transport efficiency. Although gross/net ratios typically vary from 1.4 to 4.0 for fully loaded wagons and upwards from there for part load situations, this is not such an intractable problem as it seems at first, and it is possible to develop, from the generalised performance curves based on total trailing load, a diagram which expresses the energy efficiency in terms of net tonnes of freight carried.

In this diagram, shown in Figure 3, curves delineate three adjoining areas representing the bands in which operations are likely to occur under favorable, typical and adverse conditions. Since unfavourable conditions, mainly steep gradients, also effectively limit the total trailing load which can be hauled per locomotive, this lower boundary is only drawn as far as a net load of 800 tonnes. Many of the circumstances causing train performance to fall in this lower area are associated with ruling grade loads limited to about 600 gross tonnes. Figure 3 also shows actual data points for the Trans Australian Railway superimposed on the curves derived from the Eastern States data.

The distinction between favourable, typical, and adverse conditions is obviously somewhat flexible and subjective. In fact, there are not three separate categories, but a continuous spectrum of operations, and Figure 3 should be viewed with this in mind.

As an indication of the variability which actually occurs, it may be noted from Figure 3 that westbound operations between Kalgoorlie and Perth occur with net loads over 1000 tonnes per locomotive and achieve nearly 8 tonne km/MJ, whereas main line operations in the East can occur with net freight loads as low as 200 tonnes per locomotive and a corresponding performance of about 0.8 tonne-km/MJ--one tenth of the Kalgoorlie-Perth performance and comparable with typical trucking operations. Although no hard data have been collected for branch line performance, it is expected that this would be still lower.

Terminal Activities

In addition to the en route fuel used in the linehaul vehicle, the amount of fuel used in shunting of rail vehicles and other terminal activities

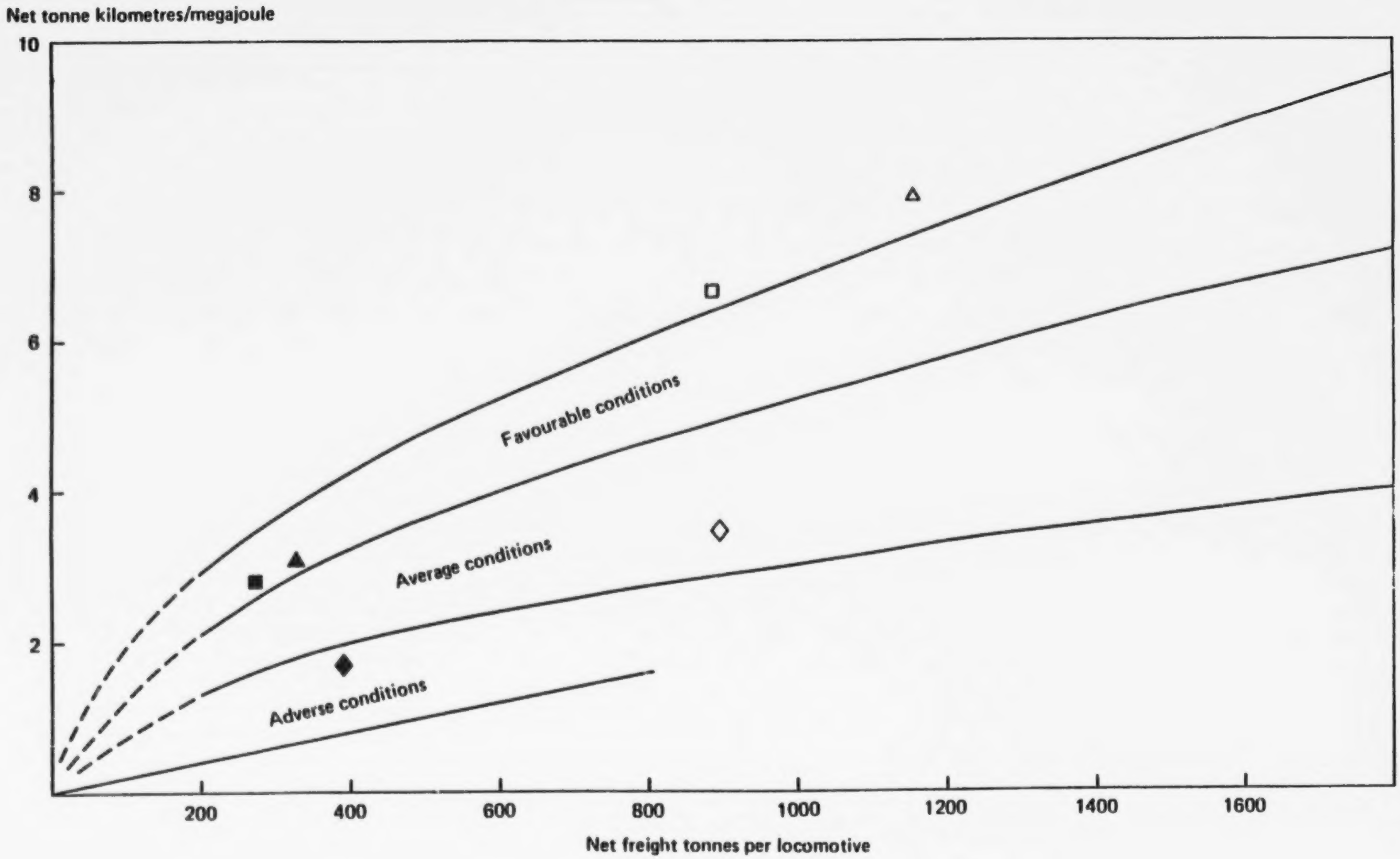

FIGURE 3
RAIL FREIGHT NET ENERGY EFFICIENCY DIAGRAM

△ Kalgoorlie-Perth single header
▲ Perth-Kalgoorlie single header
☐ Kalgoorlie-Perth double header
◇ Port Augusta-Kalgoorlie double header
◆ Kalgoorlie-Port Augusta double header
■ Perth-Kalgoorlie double header

associated with cargo handling must be considered as part of the total linehaul fuel consumption. These terminal activities are of course related to tonnes throughput rather than tonne kilometres. The approach taken here is therefore to consider first the fuel consumption per tonne and then determine how this influences the total picture.

For costal shipping, the fuel consumption and total cargo throughput at the ANL Terminal in Melbourne were estimated and it was found that 438,880 litres of fuel were used in handling a total of 2,592,000 tonnes of cargo, or 0.17 litres per tonne. Since each tonne of cargo carried on a ship will go through two terminal handling operations this leads to an estimate of 0.34 litres per tonne (13 MJ.t) for the total terminal energy use. This represents an adjustment of up to 3% of the en route fuel consumption for terminal handling.

There will be a limited amount of vehicle movement in road terminals which is analagous to rail shunting. This activity will normally be carried out by the linehaul prime mover, and the corresponding fuel consumption will be embedded in the en route data. No separate treatment of fuel use at road terminals is therefore considered necessary.

The amount of fuel used in rail shunting is influenced by many factors, which include the mix of freight and destinations combined in a single train, the layout of shunting yards and the type of locomotive and method of operation. Data on shunting fuel use was provided only for the Trans Australian Railway, and although the data available is too thin to permit any rigorous and generalised estimation of shunting fuel use, it suggests that reasonable estimates would be 0.35 litres per net tonne for an end of line terminal, 0.70 litres per net tonne for a junction involving both train breakdown and makeup operations for the same freight, and 0.05 litres per net tonne for a minor junction involving only the addition or removal of a few wagons from a through train.

The effect of this shunting fuel use on the total linehaul operation will obviously depend on the stage length and characteristics of the mainline operation. Applying these estimates to the corresponding mainline fuel consumption has the effect of increasing the Adelaide to Kalgoorlie fuel used by 8% and the Kalgoorlie to Perth fuel use by 16%. If the same estimates are applied to a shorter Eastern States haul such as Sydney to Newcastle the additional consumption of 0.35 litres per tonne at both Sydney and Newcastle and 0.05 litres per tonne at one intermediate point adds 45% to the mainline fuel consumption.

Route Circuity and Feeder Services

One of the main features of contrast between the freight modes is that in transporting a consignment from origin to destination, the use of the sea mode will always involve the use of feeder services at either end of the linehaul, rail will usually involve the use of such services, and road will frequently (but not always) avoid their use. In making an intermodal comparison of energy use, it is essential that these aspects should be examined, and it is convenient to deal with this at the same time as the effect of variations in linehaul distances, or route circuity, between modes.

The number of possible combinations of origin and destination is immense, and the number of ways in which linehaul and feeder services may be combined is therefore also immense. If in addition the possible variation in en route and terminal fuel consumption is considered, it becomes clear that to attempt to make a generalised comparison between the modes based on a single parameter such as distance would be both inappropriate and futile, and a case by case examination is required.

It is not feasible in a paper of this length to discuss examples in detail. However, it may be noted that route circuity considerations for the interterminal component will almost always favour road, with rail second and sea last. For example, the Sydney-Melbourne distance by sea is about 20% greater than the road distance. It is also clear that for distances in the 200-300 km range a feeder service of as little as 20 km at each end can add very substantially to the effective route circuity disadvantage of rail and sea vis-a-vis road and can result in the road mode being more energy efficient overall.

Conclusion

It is worth restating at this point that if meaningful comparisons are to be made between modes, they must be based on comparable tasks. Also, the efficiency of each mode is sensitive to the operating conditions, and no general conclusions concerning the relative efficiencies of modes should ever be applied to a particular operation without taking account of the specific operating conditions which prevail. Given the caveat, and that this paper is based on a study of non-urban, non-bulk freight movement in Australia, the following general conclusions can be drawn.

- In their present form Australian mainline railways have the potential to be more fuel efficient than either sea transport (as represented by the coastal movement of containers in the MV Melbourne Trader) or road haulage.

- The quantity and quality of information available on the loadings being achieved by the rail systems do not make it possible to determine to what extent that potential is actually realised.

- From the fuel efficiency characteristics of railways as estimated in this study, it is probable that long distance mainline freight trains, as they are presently operated between major cities, are significantly more fuel efficient than road and sea.

- For shorter distances and smaller train loads (branch line operations), and if quite reasonable assumptions are made about the net train load, rail appears to be marginally less efficient than road. As net train loads fall below 300 tonnes, the comparison becomes increasingly unfavourable to rail.

- The fuel efficiency of rail transport is markedly affected by terrain, both directly by influencing the fuel required to haul a train of given mass, and indirectly by determining the maximum trailing load which can be hauled. As a consequence, the best efficiency which can be achieved on mainline rail freight operations varies considerably (by a factor of at least 4) between different routes.

- Shunting of rail vehicles and other cargo handling activities adds to the fuel used in linehaul operations by rail and sea. The proportionate increase depends on the length of the linehaul operations, but in the case of coastal shipping between capital cities it appears to be about 3%, for long distance rail operations (e.g., Adelaide to Perth) it is about 8%, and may add as much as 45% to the linehaul fuel consumption on shorter routes such as Sydney to Newcastle.

- The fuel efficiency of road transport does not appear to be significantly influenced by the route characteristics and is mainly determined by the amount of load carried on each vehicle.

- Rail and sea are generally at a disadvantage compared with road in the matter of route circuity and the need for feeder services. This does not negate rail's inherently greater efficiency on mainline routes, but can become very much more significant for branch lines.

Conversion Factors

1 Btu = 1.055 KJ
Energy Content of diesel fuel = 38.4 MJ/L

Acknowledgement

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SOCIAL IMPACT ASSESSMENT PUT TO PRACTICAL USE FOR BETTER TRANSPORTATION AND BETTER URBAN DEVELOPMENT

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Abstract

The careful review and analysis of environmental effects of surface transportation projects is only valuable in so far as it can be put to practical use. This requires that the effects be understood, recognized by key parties and acted upon to the greatest extent possible. Only an effective and continuing interaction of environmental analyst, community and implementing agency can accomplish these objectives. The careful selection and use of social analysis methodologies may inform this process, but they are of no use without the interaction of those affected, those designing the system, and those elected to make the critical decisions.

The objective of this paper is to describe the effective interaction of analyst, community, and agency at critical stages in the transportation planning and design process and to draw from personal experience a variety of case studies which illustrate the practical applications of such an interaction.

The development of social analysis techniques from an early infatuation with numerical measures to a more realistic respect for informed judgment is reviewed. Six stages of transportation planning and analysis are outlined, research tasks for the environmental analyst are described, and a parallel set of objectives for community/analyst/agency interaction are provided.

If the goal is to make future investment in surface transportation systems a positive force in urban development and revitalization, a practical application of social impact assessment can be a critical factor in achieving that goal.

Introduction

The review and analysis of environmental effects of surface transportation projects is only valuable in so far as it can be put to practical use. This requires that the effects be understood, recognized, and acted upon. Only an interaction of environmental analyst, community, and implementing agency can accomplish these objectives. The careful selection and use of social analysis methodologies may inform this process, but they are of no use without the interaction of these key parties.

The objective of this paper is to describe the interaction of analyst, community, and agency at critical stages in the transportation planning and design process and to examine a variety of case studies which illustrate such interactions.

Effects on Human Use of the Environment

The impacts of primary interest here will be those which affect community form, life, vitality, eccentricities, networks, and character. At times, these impacts may flow directly from the transportation project itself: loss of homes, businesses, open space; creation of physical barriers; or changes in accessibility. In some instances, the understanding of these impacts is dependent upon other more technical analyses of air quality, noise, congestion or accessibility. Where the functioning of schools, hospitals, parks, or libraries will be constrained, where induced development will strain or exceed the capacity of community services and utilities, where clear changes in land use activity can be anticipated, where the socioeconomic mix of residents or the size and boundaries of cohesive neighborhoods will be affected, the interaction of analyst, community, and agency in the identification and mitigation of these effects will be essential.

Infatuation with Numbers

Over the last ten years we have seen a spectacular rise and fall in the application of computerized systems analysis techniques to the sizing and routing of surface transportation systems. Once these models had proven their effectiveness in simulating the elaborate network of highways, arterials, and collector roads in urban areas or the system distribution characteristics of urban transit operations, they began to be applied more and more broadly. In the analysis--especially the environmental analysis--of transportation projects all answers were expected to flow from the computer.

But the approach when used for environmental assessments was unwieldy. Outrageous amounts of time and effort were spent just nursing the model into a reasonable reflection of reality. The approach could not be easily used to review new alternatives, respond to interesting suggestions or test a broad range of different mitigation measures. It was too costly, too detailed, and too time-consuming.

It is now clear that once the detailed technical analyses have set a certain standard for a roadway in terms of basic capacity needs, configuration, safety factors and others, time is better spent fitting and adjusting the basic configuration to the realities of the surrounding physical, environmental, and political territory than nursing computer models. If this is done, the transportation system is more likely to be built, to be a positive contribution to the area-wide system, and more likely to have a minimum of severe environmental impacts.

A Parallel in Social Impact Assessment

The development of social impact assessment techniques is similar--moving from the detailed application of sociological techniques and rating systems to a recognition of the critical interaction of data and informed judgment. In the early days following the National Environmental Policy Act of 1969, all attention was focused on developing techniques for analysis of physical impacts. As these became more established, a similar technical basis for the analysis of social impacts began to develop. Publications such as the following led the way.

- Highway Improvement a Factor in Neighborhood Change by J.E. Burkhardt (1971)
- Methods of Evaluation of the Effects of Transportation Systems of Community Values by G.E. Klein (1971)
- Social Characteristics of Neighborhoods as Indicators of the Effects of Highway Improvements by Marshall Kaplan, Gans and Kahn (1971)

A variety of sociological techniques were adapted to the transportation impact assessment process. But, the technical approach was often blown out of proportion. In an effort to speak the language of the transportation engineers, analysts began an ill-fated search for numerical indices. The goal was to reach a "bottom line," a number which would tell you which route was more socially acceptable.

More recently, others such as Kurt Finsterbush and C.P. Wolf, editors of Methodology of Social Impact Assessment (1977); James McEvoy III and Thomas Dietz, editors of the Handbook for Environmental Planning (1977); Lynn Llewellyn, editor of Social Impact Assessment: A Sourcebook for Highway Planners (1975); and C.P. Wolf in his Social Assessment and Environmental Design (1979), as well as Skidmore, Owings & Merrill, as authors of a series of environmental assessment guidebooks prepared specifically for the United States Department of Transportation, have rescued the more practical and reasonable suggestions of earlier texts and have begun to stake out a clear role for subjective judgment. The concept of a Preliminary Assessment (an early identification of impact categories which really matter and therefore will get most of the analysts' attention) and an emphasis on use of informed judgment and effective presentation of technical information have moved the social impact assessment process to a different plateau.

It is clear today that once a basic data profile has been established, less time spent in number crunching and more spent facilitating communication between communities and decisionmakers will enhance the quality and sensitivity of surface transportation planning.

Interaction of Analyst, Community, and Agency

An open, well-organized, effective interaction of analyst, community, and agency is essential to the identification of impacts on the social characteristics of an area. It is equally important in the design of measures to mitigate adverse effects or take advantage of beneficial ones.

A first step is to gather the right data--at least as much through direct contact and discussion as through socioeconomic profiles and impact models. Considerable effort must then be directed at painting the right picture--identifying the size and boundaries of cohesive neighborhoods, considering the quality and type of housing, commercial, and employment centers, and determining the attitudes of residents toward each other and their environment. Once impacts are identified and evaluated, mitigation measures or plan changes must be agreed upon. Finally, a monitoring effort must be established to assure that this time and effort has not been wasted.

One of the first questions to be answered is: what makes an open, well-organized, effective interaction of key parties in the assessment and design of surface transportation systems?

An "open" process is one in which information is made available to all interested and potentially interested parties. This requires a combination of meetings, publications, and informal contacts with existing or specially formed community organizations. It is critical that the meetings be regular, well publicized, and continue throughout the planning and design and construction process. These formal sessions must be complemented throughout by smaller informal sessions in which a more frank interchange may take place, a useful contact is made, or the framework for a compromise is worked out. Technical analysts who are actually performing the environmental analysis must be present and must be prepared to listen, respond, and deal positively with issues which arise.

Objectives for Interaction at Various Stages in the Transportation Design Process

The following discussion will highlight the objectives for community interaction and social impact analysis at six stages in the transportation design process. At each stage, research tasks of the environmental analyst are described, and a parallel set of objectives for community/analyst/agency interaction are provided.

Stage 1: Understanding Existing Conditions

Research Tasks

An early step in an environmental assessment process is to review existing conditions with an eye toward understanding existing social characteristics and trends. The basic format of this research can be a community profile, based largely upon existing data and supplemented by additional research, surveys, and interviews where necessary. Useful information for the Community Profile may be found in:

- local/regional master plans or land use plans,
- U.S. or community census reports,
- maps of population density,
- lists and locations of community facilities and services,
- lists and locations of recreational or open space resources,
- descriptions of historic or cultural resources data on community boundaries (political, service districts, barriers, demographic demarcations, etc.), and
- listings of relocation resources if they are likely to be required.

Elaborate statistical analyses, if required at all, should be delayed until a preliminary assessment of environmental effects can focus such efforts on impacts of real concern to the community and decisionmakers.

Interaction Objectives

An effective interaction process at this early stage can give the community profile a sense of reality. The analyst can initiate a series of structured interviews, open discussion meetings, and site visits using community descriptions, photo essays, and mapping exercises as catalysts for discussion. Interaction at this stage should be aimed at reaching an agreement on:

- a basic profile of social, economic, human environment characteristics;
- a description of past and future trends for changes in those characteristics; and
- understanding of less quantifiable characteristics such as sense of place, cohesion, vitality, etc.

Many of the definitions of these characteristics worked out by social researchers such as Finsterbush, Wolf, Manheim, McEvoy, or Deitz should be confirmed through direct interaction with area residents, officials, planners, and community leaders.

Stage 2: Description and Preliminary Assessment of Proposed Transportation Improvements

Research Tasks

The tools at this stage include summary descriptions, maps, matrices, and even perhaps some initial perspective sketches, plans, and cross sections. With these tools, designers, engineers, and environmental analysts can describe the basic location, size, timing, construction phasing, and operational characteristics of the proposed transportation system. Looking briefly at the full range of potential impact and applying existing data and rules of thumb this early, often generic, description of system alternatives is usually sufficient to perform a preliminary assessment.

Interaction Objectives

Combined with a community review effort, this system description and preliminary assessment of impacts can:

- help to develop more realistic and buildable alternatives for detailed review,
- eliminate alternatives which are totally untenable for community controversy or environmental impact reasons,
- develop an initial sense of mitigation measures which would support community goals, and
- focus all later environmental assessments efforts on areas of real interest to the parties involved.

Formal meetings, informal interviews and mailings can be used to develop a pragmatic sense of which people, areas, and community objectives will be served by the proposed improvement--and which could or should be served through project modification. The results are unlikely to reflect the varying concerns and points of view in the community and may further influence decisionmakers than an accounting of ridership projections, or time saved in the daily commute.

Stage 3: Development of Transportation Alternatives

Research Tasks

The analyst can participate effectively in the establishment of alternatives which will meet the requirements of environmental laws and regulations (e.g., inclusion of the No-Build), and the requests of the community and the needs of the decisionmakers. The challenges at this stage are to insure that alternatives to be analyzed are kept to a reasonable number, that alternatives which reinforce positive community characteristics are included, and that sketch designs reflect preliminary assessment findings on mitigation needs.

Interaction Objectives

Community involvement in the establishment of alternatives can help to assure that modifications are made which will avoid later objections. This may require an added alternative or two to test and display community recommendations or merely agreement on a set of mitigation measures.

Stage 4: Assessment of Alternatives

Research Tasks

The responsibility of the analyst is to provide a scenario of impacts for each of the project alternatives. This will require reasoned arguments, reference to profile data, maps, photos, citations from structured interviews, and the documentation of community concerns as expressed by improvement sponsors, officials, participating citizens, community representatives, local business people, and others. It must be also the analyst's responsibility to present the essence of the impact scenario using the appropriate degree of quantification and/or modeling.

Interaction Objectives

If the analyst works with the community, their participation, and the process of presenting, revising and organizing findings with them can replace this reliance on more elaborate statistical analysis techniques. The first challenge is to translate technical findings in other impact areas (noise, air quality, etc.) into measures, statements, sketches, films, or charts which make sense to all participants and can be described in terms of social impacts. This may mean translating carbon monoxide levels into potential immediate and long-term health effects, or describing decibel levels in terms of disturbance at specific sensitive receptors such as schools, hospitals, and public gathering areas. Community meetings and discussions can then be used to identify, describe, and project impacts on the social characteristics of the community.

Stage 5: Decisionmaking

Research Tasks

The presentation of environmental information is as critical as the assessment process itself. To be used at all, the findings must be organized carefully and clearly, impacts common to all alternatives summarized, and differences among alternatives highlighted. The best preparation for this stage is to document the community interaction process throughout the last four stages.

Interaction Objectives

The analyst and community can initiate the process of evaluation which ultimately rests in the hands of decisionmakers who will exercise final judgment on the transportation improvement. *Where effects can be quantified*, where there is general agreement on prediction techniques and where clear standards or criteria exist, this task is relatively straightforward. Unfortunately, data are soft and consist of perceptions, attitudes, or preferences. And ultimately, the evaluation of even the technical findings will rest heavily upon public policy considerations and personal preferences.

The following key factors may assist in better organizing the decisionmaking process:

- the number of impacts illustrating cumulative effects;
- the magnitude of changes anticipated;
- the type and extent of exposure expected--number of people, area, timing, and sensitivity of impacts;
- degree of irreversibility of impacts;
- likelihood of conflicts with local, state or federal policies; and
- level of public interest, concern, or controversy.

General agreement on the method and content of the presentation of findings to decisionmakers will also help facilitate informed decisionmaking.

Stage 6: Monitoring of the Design and Construction Process

Research Tasks

Involvement of designers and engineers in the social impact assessment process will pay off in the development of detailed design and construction specifications which are sensitive to those environmental findings. But nothing can replace the periodic review by environmental analysts themselves and periodic reassessment as detailed designs develop. Here, the researcher must translate back into technical language the mitigation actions developed in the assessment process.

Interaction Objectives

In a long and elaborate design process it may also be useful to involve key community participants in periodic presentations and reviews. This has often been accomplished effectively in major projects through a continuing newsletter or newspaper format.

Social Impact Assessment Put to Practical Use: A Few Case Illustrations*

The case illustrations which follow demonstrate the impacts which knowledge of and continuing contact with a community and its social/economic/aesthetic concerns can have on the location, construction procedures, and detailed design of a transportation facility. In every case, though the designer or engineer was required to relinquish the drawing boards for the more uncomfortable forum of the local meeting hall, the City Council chambers or the business association breakfast, he or she can point repeatedly to portions of the final design which were clearly affected and improved by the process.

These illustrations cover:

- a major extension of a rapid transit line through high density urban areas in Metropolitan Boston ($620,000,000 estimated construction);
- design of a new rapid transit station at one of the most congested and well-represented crossroads in America--Harvard Square, Cambridge, Massachusetts ($71,000,000 construction cost); and
- a bus transfer facility in a declining older downtown, Brockton, Massachusetts ($588,000 construction cost).

Case 1: A Major Rapid Transit Extension

The concept of extending the Massachusetts Bay Transportation Authority (MBTA) Rapid Transit Line, the "Red Line", to the northwest of Boston grew out of an extensive metropolitan wide transportation study completed in 1972--the Boston Transportation Planning Review (BTPR). Relying upon the BTPR findings, Governor Sargent established a transportation policy favoring public transportation over the continued construction of major radial highways into Boston. Initial environmental analysis and extensive public involvement was used to reach initial alignment and service decisions on the Red Line extension.

The Red Line extension was then subject to an Environmental Assessment Report and Environmental Impact Statement. In this forum social impacts were again analyzed and more detailed criteria for design established. The most dramatic effects of community involvement throughout this process related to (1) alignment, (2) construction techniques, and (3) mitigation measures during the extensive construction period.

Metropolitan Scale Transportation Decisions

At the metropolitan scale during the BTPR studies, the interaction between analyst and community occurred largely through public meetings and presentation to decisionmakers. Extensive community profiles were developed and displayed on charts and maps covering the full Boston region. In the case of the Red Line extension, the primary decision focused on mode, station locations, and the ultimate length of the service extension.

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*Slides will be used to illustrate these cases.

Once a mode decision was made to extend the rapid transit line, the most dramatic interaction focused on the choice of stations. Having analyzed four primary routes from Harvard Square to Alewife--including displacement, land development, trip generation, traffic and cost implications--it soon became clear that unless the full build option was chosen, the extension itself would probably never go through. The decision was made in favor of four new stations in the first segment (Harvard, Porter Square, Davis Square and Alewife) largely in response to a very effective lobbying effort for Davis Square by the City of Somerville. The logical engineering and first cost conscious choice would have been a less circuitous route. But Cambridge and Somerville prevailed with a broader view of economic opportunities for the worn out commercial centers of Porter Square and Davis Square.

Decisions in the Environmental Assessment Forum

The regional decisionmaking process settled a number of major issues but left a great deal of fine tuning to the Environmental Assessment and Preliminary Design process which followed. At this stage, the interaction of community and analyst was expanded into a structure of Task Forces and became a continuing and intensive search for consensus.

The process is of interest for its extensive structure. It included a Transportation Advisory Group or Task Force at each station, a Red Line Working Committee to coordinate corridor-wide issues, continuing workshops, presentations and informational meetings, development of demonstration models for educational purposes, films on construction methods, corridor libraries, and a continuing interface with policymakers along the corridor.

The practical application of all these meetings and research reports came in working out a series of extensive and detailed mitigation actions which would make this major transportation improvement acceptable to the surrounding community. Those who have lived through two years of construction to date are certainly better off for the decisions made. The extensive list of mitigation actions developed includes:

- minimal takings or displacement (15 businesses along the full corridor);
- a project profile which is completely underground for the full 6.5 mile length--including deep bore through the most densely developed areas;
- traffic maintenance throughout construction;
- protection or restoration of historic areas;
- extensive safety and security measures in direct response to community concerns;

- extensive new pedestrian amenities at stations including free passageways under major streets; and

- continued support for joint development planning and traffic analysis carried out by the local affected community.

Case 2: Design of a New Subway Station

This case illustrates the practical application of social impact assessment during the detailed design of a major combined rapid transit and bus transfer facility underground at Harvard Square, Cambridge, Massachusetts. Skidmore, Owings & Merrill was selected as architects for this station by the MBTA and began design work in 1976. Designers were given a set of design criteria and mitigation actions which were worked out in schematic terms for the Environmental Assessment Report. But there was a great deal more analysis to be done before those impact parameters could be translated into detailed design. This corresponds to the "monitoring" period where periodic reviews and added research may be required.

Key design decisions which relate to social impacts and which could only be made at this stage of design are listed below.

Maintenance of Traffic

Designers were given the charge that traffic would be maintained in two directions on all roads through Harvard Square throughout the five-year construction period.

The construction procedures developed included two key components which were able to more than satisfy the original community requirements. First, a cover and cut (a modification of the Milan method) rather than a cut and cover approach was used through most of the Square. This allowed for maintenance of traffic at surface level rather than 3-4 feet above ground as originally planned and a dramatic reduction in noise levels from what would have been the case with trucks and cars at ear level.

Secondly, slurry walls were used throughout the central area of the Square which provided the best possible protection for commercial buildings and Harvard University buildings which were sometimes within three feet of the new station walls.

Construction Period Mitigation Scenario

Based upon extensive meetings with local business people and residents, a changing scenario of construction impact mitigation was agreed to and has been carried out to date. With construction within three feet of the fronts of shops, banks, and movie theaters, it was critical not only that access and views of signs and front doors be maintained. Special temporary construction was authorized for a famous newsstand, which had become both the symbolic and geographic center of Harvard Square pedestrian activity, to remain in the Square throughout the period. Decibel limits, controls and checks on construction equipment and daily scheduling limits were set to meet Harvard University and city concerns as to noise effects. Finally, an extensive program of temporary landscaping was established to soften the visual impact of construction areas.

Historic Properties

Designers began with a list of historic properties and districts, and methods were developed and reviewed to protect these landmarks. However, it was not until the design period that the central structure in the Square--the kiosk which served as the entrance to the old subway station--was designated as having historic value. After months of design studies and reviews the resolution of this problem met the desires of all parties, maintained the structure in the Square as a newsstand, and provided for continuity in the redesign of pedestrian areas.

Surface Restoration/Redesign

Perhaps the most dramatic effect of social analysis at the design stage is reflected in the restoration plan for surface roadways and pedestrian areas in Harvard Square. Research methods included detailed traffic counts and flow analyses, time lapse photography of pedestrian movements, mapping of pedestrian routes and volumes and extensive meetings with a citizen group which called themselves "Places for People." The results included two extensive new pedestrian plazas, widened and repaved sidewalks, underground free zone crossings for pedestrians, new entrances to the subway station, kiosks, bollards, trees, plantings, benches, and lighting in locations reviewed and approved by local representatives as well as the MBTA.

Case 3: Downtown Bus Transfer Facility

This case represents one successful example of a surface transportation facility used consciously and imaginatively to satisfy social goals. In the setting of older downtowns, whether declining or holding their own, the interface with public transportation is a key element in continued economic, social, and aesthetic viability.

In Brockton, Massachusetts goals set for the new Brockton Area Transit (BAT) system were to improve the quality of the urban environment and bring people back downtown by creating an attractive pedestrian experience and dependable bus service. There were three key elements to its success: first, a pulse system that brings all routes to the downtown every 20-30 minutes for transfer; second, blanket coverage of the city--95% of the city's 100,000 residents live within a five minute walk of a bus stop; and third, an attractive, smooth functioning transfer facility in the heart of the declining downtown.

Since the BAT system was established six years ago, the original ridership has increased seven-fold from 2,000 to at least 14,000 riders per day.

There is a new sense of pride and heightened reinvestment interest in downtown. The Mayor's last campaign claimed that without him, Brockton would have "missed the bus."

Location Decision

Faced with complaints of ugly, smelly buses lining up on downtown streets, it was originally proposed that the transfer facility be located on the edge of town. BAT administrators, with political support, insisted that the pulse transfer occur downtown and in fact instituted a two-hour free transfer time to let bus patrons shop downtown.

Design of the Transfer Facility

A bus transfer facility need only be a crossroads where buses meet and people transfer. But viewed more imaginatively, it can be a major, attractive trip generator for downtown commercial activity.

In Brockton, the facility was located off-street behind a main street commercial block and designed specifically for the operations of the pulse system. A pleasant pedestrian plaza with attractive shelters, seating, and fully established trees was created. Landscaping and paving extend to Main Street and the nearby City Hall, and special landscape screening is provided for a nearby historic landmark structure.

Through interaction between community and designer, the anticipated "ugly, smelly" bus facility has become an oasis of trees in the downtown. An elderly center has been established where patrons wait out of the weather. Several commercial enterprises have improved and opened their stores and restaurants to the rear facing the new plaza.

Accessibility

Aside from the social and economic impacts which flow from physical changes, the impacts of the transportation system itself are dramatic. Increased mobility has been a tremendous benefit to the old and the young of Brockton. It has given new life to community facilities such as the Art Museum which now find themselves accessible to a broader portion of the population. Increased employment opportunities have been demonstrated for those without cars.

Conclusions

Through the 1980s, and most likely into the 1990s, we will be working with increasingly scarce resources for the maintenance and extension of surface transportation systems. Use of effective analyst, community, and agency interaction in the assessment and design of those improvements can help to smooth the way and assure a more sensitively designed system. This approach can be applied at almost any stage of transportation planning and design and can be used by decisionmakers to assure that the most important adverse effects are avoided or mitigated and that potential advantages are seen in the broadest possible perspective. If the goal is to make future investment in surface transportation systems a positive force in urban development and revitalization, a practical application of social impact assessment can be a critical factor in achieving that goal.

ENVIRONMENTAL IMPACT ASSESSMENT IN EUROPE: A REVIEW OF THE PRINCIPAL CHARACTERISTICS AND AN EXAMINATION OF ITS EFFECTIVENESS

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Abstract

The paper examines the procedures that have been developed to assess the environmental impact of new developments in Europe, with particular reference to procedures for integrating environmental considerations into highway planning. The paper is principally a review of the main European EIA developments, presenting an analysis of EIA in several European countries. However, it also examines the underlying differences between the United States and European approaches and examines the effectiveness of the procedures in achieving the objective of integrating environmental factors into the decisionmaking process and in satisfying the public's concerns about potential impacts.

Introduction

The environmental impact assessment (EIA) procedures that have evolved in Europe are fundamentally different from their counterparts in the United States. There are perhaps two main reasons. First, there are the differences in the political systems: a European citizen has little opportunity to challenge or participate in the decisions of government except through the ballot box; challenges through the judicial system are rare and usually fail. Moreover, the marked division between the elected representatives and the rest of the government machine is distinct, the latter being staffed by career officials whose roles are not affected by political changes. As a result, European government officials perhaps do not feel the need to be as responsive to public concerns as are United States government officials.

Second, there were already procedures for examining the consequences of new developments in most European countries before environment became a major issue. Therefore, there has been a tendency to integrate environmental considerations into existing decision frameworks.

This contrasts with the approach that has developed in the United States at the Federal and State levels following the National Environmental Policy Act (NEPA). In this case the EIA procedures themselves have provided a framework for examining all aspects of new proposals, and "environment" has been interpreted in the widest possible sense. Additionally, the procedures have often been used as a means of challenging governmental proposals with a view to preventing or at least delaying their implementation.

In contrast, few European procedures bear any real relationship to their United States cousins. Below we review the main procedures under the heading of "EIA," but this term should be considered a general term without the connotations of the United States system. We also examine in more detail how environmental considerations are taken into account in highway planning, and finally we review the effectiveness of European systems.

Status of EIA in Europe

Formal EIA Procedures

There is existing or proposed legislation requiring that environmental impact assessments be undertaken for specified activities in France, Ireland, Sweden, the Netherlands, and Norway. Preliminary proposals have been made in Belgium and Greece. In Germany there are internal administrative procedures to supplement legislation requiring that environmental considerations be taken into account in the decisions. In the United Kingdom and Denmark, environmental considerations may be taken into account in the land-use control planning procedures. In Sweden, Denmark, and Norway the environment is also taken into account in applications for environmental protection approvals. There is a proposal for an EEC Directive on environmental impact assessment, but this is not expected to receive the assent of the EEC Council of Ministers.

Specified Activities

Most countries with an existing or proposed system have adopted a "positive list" approach, that is specifying which activities require an EIA. France also has lists of activities for which only a simplified EIA is needed as well as a list of exemptions. In Ireland, it is intended that EIA be undertaken for only large-scale developments (in excess of I £ 5m).

While most environmental assessments are concerned with new project developments, a number are carried out on proposed land-use plans. The Dutch Government intends that EIA also be used for proposed policies.

Purpose of EIA

The focus in Europe is on examination of the impact on the natural environment. Some of the legislation (e.g., the proposed Dutch law) specifically excludes, for example socioeconomic impacts, on the grounds that these will be examined separately by the decisionmaker. A second feature of the European procedures is that in most countries the environmental assessment requirements are tied into the existing approval procedures (planning permission, pollution control licenses, highway development authorisation, etc.). In nearly all cases, responsibility for requiring and in some instances carrying out the EIA lies with the government authority responsible for the approval.

Scope of EIA

In France, Ireland, and the proposed Dutch system, a report on environmental impact is required; and the topics to be covered are specified. In other countries the competent authority may request that certain information be produced with the application for approval. These requirements vary, depending on the nature of the application. In Denmark, for example, to gain approval for a "heavily polluting enterprise," information must be supplied on raw materials used, emissions, risks, etc., while to gain approval for public works in rural areas (from a different authority) the emphasis is on the natural environment. Only in Sweden, Germany, and the proposed Dutch procedures is there an explicit requirement to examine the alternatives. In France, the reasons for selection of the proposal should be included, and this may require that the environmental impact of other alternatives be reviewed. (Recommendations on environmental considerations to be taken into account in highway planning in three countries are shown in Table 1.)

Public Participation

As we noted at the outset, European citizens traditionally have had limited opportunities for involvement in government deliberations or decisions and EIA procedures are no exception. Under German procedures the results of the EIA are rarely made public. In France the report must be made public after the decision has been made although the authority is encouraged to release it earlier. In all the other procedures the environmental assessment information is made public prior to the decision, and there is an opportunity for the public to comment. In the proposed Dutch system the public may also comment prior to the study (at the scoping stage); in France early public involvement is recommended for some procedures (including roads), and in the United Kingdom there are guidelines for road assessments that recommend the involvement of the public when examining alternatives and identifying impacts.

In Europe the principal opportunity for public involvement in planning arises when public inquiry procedures are invoked for major developments. At public inquiries most parties will be able to present their views.

Environmental Assessment for Highway Planning

We discuss below how environmental considerations are integrated into highway planning in France, Germany, and the United Kingdom. These three countries have been chosen since they exemplify different approaches: France has a formal EIA system; in Germany environmental assessment is essentially an internal administrative procedure linked to existing highway approval and nature protection requirements, while in the United Kingdom environmental considerations are taken into account at the development control planning stage.

TABLE 1

ENVIRONMENTAL CONSIDERATIONS TO BE TAKEN INTO ACCOUNT IN HIGHWAY ASSESSMENT

UNITED KINGDOM	GERMANY	FRANCE
Travellers: time savings vehicle operating cost savings accident savings reduction in casualties comfort and convenience view from road delays during construction Pedestrians: amenity safety severance Occupiers (residents, industry, commerce, institutions): properties demolished noise visual obstruction visual intrusion severance disruption during construction Farming and open space: land take Users (shoppers, visitors, club members, etc.): reduction in conflict between uses noise access, convenience amenity severance loss of facilities Conservation and improvement plans and policies Transport, development and economic plans and policies Costs	Settlements Agriculture Forestry Unique areas Noise Air quality Land-take Severance Quality of settlements Quality of farmland Extent of cultivation Extent of pasture land Other flora Fauna Water quality	Climate Topography Hydrology Natural environment and ecological interests Vertebrate and invertebrate Fauna biotypes and rare species Animal migration routes Biological and fishery Quality of waters Present and future land use Infrastructure Neighbourhood constraints Agriculture Forestry Countryside/landscape Protected areas Recreation/tourism fishing hunting other Cultural heritage Scientific heritage Aesthetic heritage

Sources: United Kingdom[4]
Germany[5]
France[2]

BEST DOCUMENT AVAILABLE

France

In France, national highway developments require permission, in the form of a "Declaration of Public Utility" from the Ministry of Public Works (Ministere de l'Equipement et de l'Amenagement). Dutch declarations are subject to the formal EIA procedure. For this purpose, road plans are first discussed with local authorities, elected officials, and certain professional groups and then sent to the Minister for approval.

Following this, a public inquiry is held by a "Commissaire-enqueteur" who makes a recommendation to the Minister. It is the Minister who decides whether the development should proceed.

Examination of Environmental Impacts

For national highways costing 6mm FF or more ($1.2m) an impact study is required by law.[1] This study is presented as part of the Dossier prepared for presentation to the inquiry on the Declaration of Public Utility. There is a circular issued by the Directorate of Roads and Road Traffic in the Ministry of Public Works on the methods to be used for preparation of impact studies for road projects. This circular outlines what the impact study includes and the principles to be followed in its preparation.

A directive (at present provisional) concerning "Impact Studies of Inter-Urban Highways" accompanies the circular.[2] This contains:

- a checklist of environmental factors to be considered;
- a review of background information on impacts;
- advice on possible mitigating measures that may be used;
- advice on quantitative and graphical techniques to be used in presenting results;
- requirements governing the content of the impact study including the use of matrices (impacts vs. alternatives) for summary presentation.

There are also guidelines prepared by the Ministry of Environment.[3]

This procedure was followed in planning the A42 autoroute. The study examined the following environmental aspects: physical (land form, water) biological (flora and fauna), human habitat and activities (land use plans, noise, agriculture) sites of special interest, and impacts on landscape and mineral resources. Two alternatives were considered, one of which had been identified as the chosen proposal at the outset. In presenting the information, formal quantified techniques for measuring and evaluating impact were not used. All impacts were described narratively in the text, and summarized using a verbal scale (negligible, moderately important, important, very important).

Germany

Major highway developments require outline approval by the Federal Minister of Transport and detailed approval from provincial transport authorities. Initial route selection is undertaken by the local highway authority which has a duty to consult certain regional authorities. In exceptional cases, action groups may also be consulted. Route approval is then required from the Federal Minister of Transport, and planning approval is required from the provincial transport authority. At this final stage, the transport authority may hold a hearing to inform the public about the proposals. There are, however, no requirements in the law for public participation; individuals may appeal against the grant of planning approval once it has been granted, and only if they are directly affected.

Examination of Environmental Impacts

The Federal Highways Act (S.16) and the Federal Nature Protection Act (S.8) require that the environmental impact of new schemes be considered. Also a 1975 Cabinet resolution established "Principles for the Environmental Impact Assessment of Public Actions" which may be applied to federal roads. The local highway authority is responsible for preparing the assessment.

Guidelines for use when selecting routes are currently being prepared for the Federal Environment Agency on "Standard Assessment Methods for Environmental Effects of Trunk Road Plans." They describe a standard procedure for highway planning and alternative methods for route selection. Methods described include overlay mapping of weighted and summed environmental variables to identify a preferred route. The handbook is to include a checklist of environmental variables and details of how these variables can be assessed.

An environmental assessment was carried out on two alternative routes: the B202 highway between Kiel and Rendsburg. The purpose of the assessment was to determine which route would have minimum ecological and environmental impact. The study examined impacts on landscape, ecology, settlements, and structures and reviewed protection policies. Impacts were quantified, mapped, and weighted and summed to give a total impact score for each route. The report gives details of the techniques used to measure each variable, and results of the study group's recommendations. It was used as a document to support the proposal of the local highway authority.

United Kingdom

National truck road developments require a permit under the Highways Acts from the Minister of Transport and the Secretary of State for the Environment in the form of a "Trunk Road Order."

Trunk road planning is the responsibility of regional units of the Department of Transport. Plans are submitted first to the public for consultation, then to the Minister for outline approval and finally to a public inquiry.

The public inquiry is carried out by an inspector appointed by the Ministers. The inspector makes a recommendation to the Ministers who then make the final decision on the issuance of a Trunk Road Order. The recommendations of the inspector may be overruled. In the United Kingdom, public inquiries are perhaps exceptional, in that they provide an adversarial setting for proponents and opponents to argue their case with the assistance of legal counsels.

Examination of Environmental Impacts

In granting permission for trunk road development the Ministers have a general duty to consider the protection of the environment.

Regional units are responsible for preparing an assessment framework. Guidelines have been issued to regional units on a comprehensive framework for trunk road assessment[4,5]. They describe a standard format for presentation of information on the environmental and economic consequences of the alternatives. Guidance is given on:

- affected interests (users and policies) to be considered;
- environmental and economic impacts to be considered;
- methods and parameters for predicting impact (including monetary evaluation, verbal scales, numerical parameters);
- a matrix (impacts vs. alternatives) for comparison.

The information is presented at different levels of detail: in outline for public consultation, in summary for ministerial approval and in detail for the public inquiry. This framework approach is now applied to all trunk roads in England and Wales.

Effectiveness of the European Procedures

We have examined above the main characteristics of a number of European procedures. How effective are they? To what extent do they ensure that environmental considerations are taken fully into account in the relevant decisions?

One of the principal characteristics of the procedures is that the environmental assessment forms only one of the inputs into the decision process and is usually focused on the likely consequences on the natural environment. The authority responsible for the overall decision can in most cases specify the information required; indeed it may also be responsible for the assessment itself.

This approach has considerable advantages. In particular, it ensures that the decision group has the information it needs and in a form it can use. It overcomes one of the major potential problems in EIA: the danger of carrying out an extensive and costly study that has no practical use.

However, there is one obvious defect. If one believes that different groups within the community have varying perceptions of the environment, and if one believes that the purpose of an environmental assessment is to satisfy the community that these environmental concerns have been properly taken into account, then the procedures should allow for the involvement of groups other than the authority and the proponent in such a way as to ensure that their concerns and the alternatives they may consider valid are fully examined. Finally, there should be safeguards to ensure that a proper assessment is carried out.

Without such safeguards, there is the danger that the assessment will be manipulated to support the views of proponents and competent authorities. At worst it will become a propaganda document designed to show how little damage is caused by a particular scheme. This problem is exacerbated where there are links between the competent authority responsible for ensuring that an environmental assessment is carried out and the authority responsible for proposing a particular scheme, or, as often is the case, where they are the same authority. The problem can be overcome partly by ensuring the procedures are subject to independent review by an agency with powers to reject the EIA if the assessment is inadequate. There are plans for such an agency in the Netherlands and in Ireland.

Alternatively, full public participation can be used to ensure that the concerns of all parties are drawn to the attention of the decisionmaker. However, as noted above, in most of the procedures there is very little real participation, and this is usually limited to an opportunity to comment on the proposals.

The proposed Dutch procedures are of interest in so far as they represent perhaps the most extensive attempt to involve the public. In these procedures the public and other interested groups (e.g., other agencies) will be able to comment after the intention to do an assessment has been announced and prior to the study. Therefore, their concerns and views on possible alternatives can be voiced at this stage and, at the discretion of the authority, taken into account in the study. Furthermore, there is to be an opportunity for comment after the report has been published and before the decision.

In principle, the United Kingdom highway planning procedures (summarised above) also provide an opportunity to involve those who will be affected. In this case, some account is taken of the public's views on the alternatives and impacts in planning. Nevertheless, the system is such that the government makes the rules for the game and makes the decisions. A continuing controversy concerns the right of the public to question the need for a road and to request that the evaluation include "demand-forecasts" for alternative modes of transport.

However, when contrasting European and United States procedures, some advantages to the European approach can be seen. The strength of the United States system--that the assessment can be challenged if it fails to provide an adequate review of alternatives and impacts--has also proved to be one of its major weaknesses. The United States EIS is not designed primarily as a document to aid the decisionmaker, and it is unlikely, even with the Council on Environmental Quality (CEQ) scoping regulations, that the procedures will prove cost-effective in terms of producing information on environmental impacts of alternatives that the decisionmaker requires and can use. The European procedures (with the exception of France) do focus on information needs, but suffer from lack of safeguards to ensure that the environmental assessment reflects a consensus in the community.

It is perhaps unrealistic to expect that within the European system (or indeed within any system) EIA could be effective in supplying the information required for the decision as well as providing a real opportunity for the environmental concerns of the community to be taken into account in the decision. It is unrealistic because, as we said at the beginning of this paper, there is a tradition in Europe that government makes the decisions on behalf of the people, decisions that take account of the "public interest" and which cannot be challenged. At the same time, it is likely that over the next decade there will be further growth in public pressure for greater involvement in major decisions, such as siting of nuclear plants or building new motorways. But to satisfy this will require more fundamental changes than just the strengthening of environmental impact procedures.

Acknowledgements

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ENVIRONMENTAL CONSIDERATIONS IN THE U.S. DEPARTMENT OF TRANSPORTATION DECISIONMAKING PROCESS

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Abstract

Over the past ten years, the environmental impact statement required by the National Environmental Policy Act (NEPA) has been an important tool in the decisionmaking process of the U.S. Department of Transportation. An Environmental Impact Statement (EIS) addresses the environmental impacts of a proposed action, alternative solutions, and measures to lessen adverse effects of the proposal. The EIS is the vehicle for coordination with other agencies, public review of the proposal, and for compliance with environmental requirements other than NEPA. The paper will briefly describe the elements of environmental review procedures and the role of each element in the decisionmaking process. The Council on Environmental Quality's 1978 Regulations for Implementation of NEPA, which apply to all Federal agencies, will be discussed.

The paper will discuss how the environmental review has improved the decisionmaking process. Transportation proposals have been changed or improved through the process, and project decisions developed through the process are setting policy precedents. In addition, the EIS process has helped to identify new transportation and environmental policies.

Introduction

The subject of this paper is how environmental considerations enter into the U.S. Department of Transportation's decisionmaking process. The primary tool for integrating environmental considerations into the decision process is the environmental impact statement (EIS) required by the National Environmental Policy Act (NEPA). An environmental impact statement addresses the environmental impacts of a proposed action, alternative solutions, and measures to lessen impacts. The EIS is also used by DOT to coordinate with other agencies, obtain public review of the proposal, and reflect compliance with environmental requirements other than NEPA.

This paper will discuss how the environmental review process required by NEPA, and the procedures established by the U.S. Department of Transportation, have improved the decisionmaking process and how transportation proposals have been changed or improved by the process through selection of less environmentally damaging alternatives or inclusion of measures to reduce impacts of the proposal. This paper will discuss also how the EIS process has helped shape transportation policies and reflected new policies as they have developed. Among new policies identified in part, and implemented through the EIS process, are: policies in support of mass transit, ridesharing and better use of existing facilities, using transportation projects to retain or restore the vitality of urban areas, and minimizing impacts of transportation projects on environmentally sensitive areas.

Background: The National Environmental Policy Act and DOT

The National Environmental Policy Act of 1969 (NEPA) established a national policy of encouraging conditions under which man and nature can exist in productive harmony. NEPA directed Federal agencies to develop procedures to assure that environmental amenities and values may be given appropriate consideration in decisionmaking, along with economic and technical considerations. Section 102(2)(C) of the Act directs the preparation of a detailed environmental impact statement on proposals for legislation or other major Federal actions significantly affecting the quality of the human environment, to be used in decisionmaking on the proposal. The environmental impact statement must address the environmental impacts of the proposed action, including adverse effects which cannot be avoided, alternatives to the proposed action, and long-term impacts of the proposal. The Council on Environmental Quality (CEQ) issued regulations for implementation of NEPA in 1978.[1] The regulations provide for a two-stage process for preparation of EISs. The Federal agency proposing the action prepares a "draft" EIS and circulates it for comment to the public and appropriate Federal, State, and local agencies. The Federal agency then revises the EIS, taking into account comments received on the draft, and publishes a "final" EIS. The proposed action cannot occur until at least 30 days after the final EIS is made available to the public.

The U.S. Department of Transportation is one of the major producers of EISs in the Federal Government. Since enactment of NEPA, DOT has prepared about 2,800 final EISs. The Department has a wide variety of programs which may require preparation of an environmental assessment or an EIS. The majority of DOT EISs have been prepared for proposed highways funded under the Federal-Aid Highway Program. Other programs of the Department requiring environmental assessments include the Airport Development Aid Program administered by the Federal Aviation Administration, capital assistance to transit agencies from the Urban Mass Transportation Administration, and the bridge permit program of the Coast Guard. Assistance programs of the Federal Railroad Administration, activities of the Saint Lawrence Seaway Development Corporation, vessel and boating safety programs of the Coast Guard, and regulatory actions of the National Highway Traffic Safety Administration have also occasionally involved preparation of environmental documents.

U.S. Department of Transportation guidance on implementation of NEPA is established by a Departmental order which adopts the CEQ regulations and defines environmental decisionmaking responsibilities within the Department.[2]

A key provision of the order is that the Assistant Secretary for Policy and International Affairs, within the Office of the Secretary, must concur in final EISs for certain categories of actions before they can be approved by the DOT administration proposing the action. These categories of actions include major urban freeway and airport proposals, other major actions likely to involve substantial environmental impacts, and any action to which a State, local, or Federal agency has objected on environmental grounds.

Concurrence by the Assistant Secretary in final EISs is an important element in the Department's decisionmaking on major transportation proposals. Any proposal requiring an EIS cannot proceed until after a final EIS has been approved, filed with the Environmental Protection Agency and made available to the public, and a final decision made following this availability. The concurrence requirement thus puts the official responsible for DOT environmental policy into the decisionmaking process. The Assistant Secretary contributes to DOT decisions on independent environmental perspective and sensitivity to Secretarial policy. The operating administration officials are naturally more likely to approach decisions from the perspective of the transportation mode and programs they administer. Under this process, other Federal agencies, local officials, and citizens also have an opportunity to make their views known to a Secretarial official if they believe that their views have not been considered adequately.

How the EIS Process Has Improved Decisionmaking

Preparation, circulation, and Departmental review of the EIS provide an opportunity for improving decisionmaking in several ways. First, the public, reviewers, and the decisionmaker are informed of the adverse consequences of the proposed action. Second, the decisionmaker can consider a full range of alternatives and be aware of the impacts of each. Through circulation and review of the EIS, other alternatives sometimes are identified. Similarly, measures to avoid or reduce adverse consequences of the project are identified by reviewers. Finally, since the EIS is coordinated with other agencies, DOT has developed a policy that the EIS is the vehicle for compliance with the requirements of other environmental laws and orders in addition to NEPA. The EIS process thus provides a forum for resolution of issues. Each of these aspects of decisionmaking is discussed further below.

Disclosure of Impacts

As stated in the CEQ regulation for implementation of NEPA, the purpose of the EIS is to provide a means for insuring that the goals and policies of NEPA are incorporated into actions of the Federal Government. The EIS must "provide full and fair discussion of significant environmental impacts and shall inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impact or enhance the quality of the environment."[3] The EIS must focus on the significant environmental issues and must be supported by evidence that the agency has made the necessary environmental analyses.

Circulation of the draft EIS provides an opportunity for the public and other agencies to comment on the completeness, accuracy and objectivity of the analysis and the seriousness of the impacts, as well as provide their views about the action being proposed. The final EIS must respond to these comments and be revised as appropriate and must identify the preferred alternative. After the final EIS is approved and made available to the public, the agency may make its decision and must then prepare a record of decision which indicates how the EIS was used in reaching the decision.

In the early days of EIS preparation, the seriousness of environmental impacts was sometimes downplayed. Statements were often conclusory and self-serving. However, the discussion of impacts created public pressures for more objective EISs which are supported by systematic analysis. Disclosure of the impacts creates pressure to avoid or reduce the seriousness of impacts. Proposals often are changed significantly as a result of comments received on the EIS. One of the best examples of this is Interstate 205 in Portland, Oregon. This highway was proposed originally as an eight-lane highway. Following circulation of the draft EIS, the highway was scaled down to six lanes with a separate express busway, a bicycle-pedestrian facility, and noise abatement measures. In addition, a controversial interchange was deleted.

Another example is expansion of the airport at St. Thomas, Virgin Islands. Proposed extension of the runway required fill in adjacent bays for all alternatives. As a result of strong objections from several Federal agencies, the project was designed ultimately with significantly reduced fill requirements, and fill material was obtained from upland sources rather than dredged from the bay.

Thus, the EIS as a full disclosure document, has contributed to more environmentally sensitive transportation decisions made by a decisionmaker who is aware of the environmental implications of the decision.

Alternatives

Transportation impact statements are required to address a range of alternatives including, where relevant, consideration of other modes of transportation, or upgrading of existing facilities. This range of alternatives is frequently expanded as a result of alternatives suggested by EIS reviewers. Alternatives which in the past have been discounted or examined superficially because they could not be implemented by the proposing agency are now given increased emphasis. For example, in the highway program, transit improvements and traffic engineering strategies often are considered explicitly in EISs as alternatives to construction of a major highway. In addition to alternative routes, different highway configurations also have been examined as a result of the environmental process.

An example of broadened consideration of alternatives is the proposed construction of Interstate 93 in New Hampshire. In the early 1970s, the Department disapproved the routing of I-93 through Franconia Notch State Park under section 4(f) of the DOT Act, which provides special protection to parklands. Special legislation which would allow DOT to construct the highway with waivers of geometric and design standards for the interstate system was enacted later. The revised draft EIS addressed alternative routes which would avoid the park. Three design alternatives on the proposed route through the park were also examined--two-lane and four-lane parkway designs and a standard four-lane Interstate design. Environmental groups and the state park and highway agencies worked together to evaluate these alternatives. Ultimately, a two-lane parkway design with climbing lanes was agreed upon and the final EIS was approved for this design. The proposed project is expected to significantly improve conditions for through traffic, as well as park traffic, while significantly reducing potential adverse impacts on the scenic and recreational values of Franconia Notch. In short, the EIS process leads to broader and more complete consideration of alternatives, which results in sounder, more balanced decisions.

Mitigation

The EIS process provides a vehicle for identifying measures to mitigate adverse impacts of transportation proposals. Early coordination with other agencies and public involvement prior to EIS preparation identifies impacts which are of concern to those agencies and the public, and also identifies possible measures to avoid or reduce the impacts. Subsequently, comments on the draft EIS often suggest measures to minimize harm. Agencies with special expertise, for example the Fish and Wildlife Service, the State Historic Preservation Officer, and the Environmental Protection Agency (air, noise and water quality impacts) are key sources of recommended mitigation measures. The Department's procedures provide that the final EIS identify mitigation measures which will be included in the proposal. The Department's internal review also can suggest or require mitigation measures.

Examples of mitigation measures which have been included as a result of the EIS process are: constructing highway sections on structure to reduce impacts on wetlands, constructing noise barriers, building a highway below ground level or in tunnels to reduce noise and visual impacts, including major landscaping and bicycle facilities, and aligning an airport runway to avoid noise-sensitive or ecologically sensitive areas. Inclusion of such measures in transportation projects makes them more compatible with the surrounding environment.

Coordination

There are some 25 review and analysis requirements imposed by environmental laws and executive orders which may affect DOT proposals. Most of these statutes and orders protect a particular type of resource, such as historic, wildlife or recreation resources. It is DOT's policy that the EIS process be used as a "one stop process" for compliance with relevant environmental requirements. This concept has received growing emphasis in recent years, and the DOT environmental procedures now explicitly state that:

1. to the maximum extent possible, all environmental studies, reviews and consultations with Federal and state agencies must be coordinated into the NEPA process, and

2. efforts must be made to resolve issues so that the final EIS or the finding of no significant impact can reflect compliance with applicable environmental requirements.[4]

Implementation of this policy can present difficulties because of the conflict between preparing the environmental assessment early in the project planning so that environmental factors can influence the project approval decision versus providing detailed enough information to satisfy the special needs of the other environmental requirements.

An example of this conflict is the requirement for a "section 404" permit program for disposal of dredged or fill material in navigable waters, administered by the Army Corps of Engineers. Because of the detail needed for permit processing in the past, permits were typically applied for long after the EIS approval when project engineering was near completion. However, this often led to delays in obtaining the permit since environmental issues concerning permit activity were not raised until permit review or were raised for a second time. Since the Corps is also responsible for implementation of NEPA, there is also the potential for duplication of environmental review. In a recently signed memorandum of agreement between DOT and the Corps of Engineers,[5] it was agreed that whenever a section 404 permit will be needed for a DOT action, the Corps will serve as a "cooperating agency"[6] during DOT's environmental processing, so that DOT's environmental documents normally would serve to satisfy the NEPA requirements for both agencies. The agreement emphasizes the resolution of environmental issues during the DOT EIS stage, in order to minimize duplicate review of such issues during the Corps' permit stage. This cooperation will require that DOT EISs provide somewhat more information on the impacts of the fill activity than earlier EISs did, so that issues related to dredge or fill activities can be raised during DOT's EIS preparation.

Another example of coordinating environmental requirements into the EIS process is in implementation of the National Historic Preservation Act. This Act requires each Federal agency to consider the effect of its proposed actions on any site listed on the National Register of Historic Places before approving the action, and to give the Advisory Council on Historic Preservation the opportunity to comment on the proposal. DOT procedures provide that historic sites on, or eligible for, the National Register be identified and the effect of the proposal be discussed in the draft EIS. If consultation with the Advisory Council is necessary, the EIS is used as the basis for consultation, and any issues normally are resolved before the final EIS is approved.

As these examples suggest, in the context of the complex balancing that must be accomplished between numerous environmental, transportation and other requirements, the EIS provides a mechanism for coordination, procedural simplification and the necessary evaluation of tradeoffs.

Formulating and Implementing Transportation Policy Through Environmental Review

As noted earlier, final EISs for major transportation proposals cannot be approved until they have received concurrence from the Assistant Secretary for Policy and International Affairs. This assures that environmental policy considerations can be integrated into decisionmaking on major transportation proposals. Not only is current DOT policy implemented through this review process, but possible new policies may be identified as well.

The Office of Environment and Safety, under the Assistant Secretary, reviews all draft EISs prepared by the Department. Such reviews focus on whether the proposal is consistent with DOT policy and is environmentally satisfactory, and whether the EIS has been prepared following DOT procedures and guidance. Draft EISs normally will address a range of alternatives. If one or more alternatives has particularly serious impacts, the Office of Environment and Safety's comments may note objection to those alternatives. Mitigation measures are often recommended.

In its review of a proposed final EIS, the Office of Environment and Safety again focuses on policy considerations, and to a lesser extent, procedural compliance. A key concern of the review is whether the final EIS adequately resolves the issues raised in comments on the draft EIS. The final EIS may reflect consultation with interested Federal or State agencies in an effort to resolve issues, resulting in selection of a particular alternative location or design, or inclusion of mitigation measures. Resolution is particularly important where a Federal, State or local agency has objected to the proposal on environmental grounds.

If the major issues appear to have been resolved in the final EIS, procedural requirements have been met, and the proposal appears to be consistent with existing DOT policy, the Office of Environment and Safety recommends that the Assistant Secretary concur in approval of the final EIS. On the other hand, if problems with the final EIS are identified, there is a range of actions which may be taken by the Assistant Secretary. Depending upon the seriousness of the policy concerns or the degree of controversy surrounding a proposed decision, the Secretary may be involved personally in decisions on the final EIS.

The first option is to meet with modal administration staff and request minor changes to the EIS or proposal. If the requested changes are acceptable to the administration, the Assistant Secretary concurs in the EIS after appropriate revisions. An addendum to the EIS often can clarify impacts, incorporate modifications to the proposal, or reflect procedural compliance with a special environmental requirement. Examples of the above are a commitment to implement noise abatement measures at a sensitive location and inclusion of a wetlands finding pursuant to Executive Order 11990 and DOT Order 5660.1A, Preservation of the Nation's Wetlands.[7]

Another option is to concur in approval of the EIS based upon certain conditions. These conditions typically specify actions which must be taken during project development to further minimize harm resulting from the proposal.

Conditional approval often reflects current policy or policy under development. An example of approval with conditions, reflecting policy on mitigating community impacts is Interstate 696 in the Detroit, Michigan area. After almost a year of efforts by the Office of the Secretary, the State, FHWA, and local communities to resolve the environmental and transportation issues, the scale and design were modified and a major mitigation plan was developed. The final EIS was approved on the basis of this mitigation and conditioned upon a number of actions, including: provision of one of the highway's covered sections to the community for housing (if the community desired); development of a housing relocation plan with public participation, including possible construction of relocation housing; interface with a proposed light rail transit facility; and construction of a parking structure.

The Assistant Secretary may also nonconcur (i.e., disapprove) in the EIS or approve only a portion of the proposal. Nonconcurrence in the EIS is often accompanied with a request for further analysis and documentation of alternatives or mitigation measures. The Assistant Secretary did not concur in the EIS for the construction of I-49 in Alexandria, Louisiana because of potential conflicts with policy regarding community, housing and civil rights issues. The highway would have resulted in extensive displacement of minorities and there was concern that adequate relocation housing would not be available in the community. A detailed housing and relocation study was performed, and the EIS was later approved on the basis of the relocation plan and its conformity with the foregoing DOT policy concerns.

The EIS process also helps to develop new policy. In an effort to illustrate how the EIS process contributes to policy formulation, I will trace development of the Transportation Urban Policy articulated in former President Carter's Environmental Message of August 2, 1979 and in later Departmental guidance.

In 1978 and early 1979, a number of major urban transportation proposals had been ripe for decision--either the final EIS was submitted to the Office of the Secretary for action, or the proposed final EIS was expected to be submitted within the next year. Most of these proposals involved serious impacts and substantial controversy. Through review of the draft EISs for many of the urban highway proposals, and through review of proposed final EISs, it was apparent that there were similarities in the problems in these proposals.

- Many involved displacement of large numbers of people in communities where little relocation housing was available or displacement of a disproportionately high number of minority residents.

- The proposals were mostly traditional highway solutions to transportation problems, with little planning for public transportation or incentives to higher vehicle occupancy.

- Many proposals were for bypass highways which had the potential to stimulate growth in suburban areas rather than downtown. This would tend to increase energy consumption due, in part, to longer trips to work.

- Residents from adjacent communities opposed the project because of anticipated noise, air quality, and land use impacts.

At the same time these EISs were being considered, a number of actions were occurring outside the Department which were related to the issues identified in the EIS.

- First, in March 1978, former President Carter issued the President's Urban Policy. The policy stressed using Federal programs to revitalize urban economies, improve the urban environment, and reduce urban sprawl.

- A study prepared for the Council on Environmental Quality[8] and other studies found that federally assisted highway construction had been a major determinant of growth patterns and development, and particularly in fostering suburban sprawl-type development.

- Section 103(e) of the Highway Act, which provided the option for State and local governments to decide not to build urban interstates and instead request transfer of funds to other highway and transit projects, was amended in 1978 to provide up to 85% funding for transfer projects, compared to 80% previously. This increase in the eligible share for transfer projects made the withdrawal option more attractive to state and local governments.

- Finally, more and more local communities were expressing concern about the severe impacts of proposed urban freeways and were questioning whether improving transit facilities and service, or improvements to existing facilities, would be viable alternatives to highway construction.

A large number of EISs under consideration or anticipated to be under review had apparent conflicts with the President's Urban Policy and other expressions of concern. Consequently, a task force of staff from the Office of the Secretary and representatives from Federal Highway Administration and Urban Mass Transportation Administration was established to consider these proposals. The task force determined that the urban policy needed to be translated into a specific statement of transportation urban policy to guide future actions of the Department and advise grant applicants of the Department's policy.

The first articulation of the policy was in a speech by former Secretary Adams made in February, 1979.[9] The speech addressed five areas of concern:

1. avoiding economic impacts,

2. increasing ridesharing and transit use,

3. increasing work by minority contractors,

4. upgrading existing facilities in lieu of new construction, and

5. reforming the design and approval process for urban transportation proposals.

Each of the policy statements was shaped to some extent by the problems identified in EIS review and by potential solutions developed by reviewers and policy officials. Secretary Adams directed FHWA and UMTA to consider these policies in a May 7, 1979 memorandum. DOT was later invited by the Council on Environmental Quality to contribute to the development of the President's Environmental Message. The policy statements in the Kennedy School speech and the May 7 memorandum formed a basis for the Department's input to CEQ.

The President's Environmental Message was issued by former President Carter on August 2, 1979, incorporating the transportation policy section prepared by DOT. There are five basic directives in the Transportation Initiatives section of that Environmental Message:

1. Transportation funds should be used to promote energy conservation in transportation, and encouragement should be given to applying funds to public transportation projects and strategies such as special lanes for carpools and transit vehicles and bicycle facilities.
2. Careful review should be given to any transportation proposals which might contribute to urban sprawl or tend to attract jobs out of urban centers.
3. Careful consideration should be given to improvement and rehabilitation of existing transportation facilities and to the use of nonconstruction methods as alternatives to new facilities.
4. Major transportation projects should be utilized as a positive factor for improving the urban economy and attracting jobs to urban cores.
5. Firm actions should be taken to mitigate the adverse effects of transportation projects on the environment.

The Department's Guidance on Format and Content of Environmental Documents, now under development, will help assure that future EISs will address urban impacts, address a full range of alternatives, and incorporate mitigation measures into DOT proposals.

Conclusions

The EIS process is a vital and useful part of decisionmaking at the U.S. Department of Transportation. Circulation of the draft EIS to the public and other agencies provides a mechanism of review and comment on the transportation proposal and for identification of alternative actions and mitigating measures. Transportation proposals are changed through this process so that they are more compatible with the environment. The Department's emphasis on coordination with other agencies and compliance with all environmental requirements through the single EIS process helps to minimize delay and duplication in implementing transportation improvements. Involvement by the Office of the

Secretary in the review and approval of EISs provides a mechanism for early identification of policy issues, the development of appropriate new policy, and for assuring that current policy is reflected in the decisions made on all major transportation proposals funded or permitted by the Department.

In sum, the EIS process is not only an important tool in making better informed and balanced decisions at DOT, but it serves as the fundamental mechanism for implementing the primary objective of NEPA, that is conducting Federal activities in harmony with the environment.

NOTES

1. Council on Environmental Quality, Procedural Provisions of the National Environmental Policy Act, 40 Code of Federal Regulations 1500-1508.

2. Department of Transportation Order 5610.1C, 18 September 1979, 44FR 56420.

3. 40CFR 1501.2.

4. DOT Order 5610.1C, paragraphs 2.c. and II.b.

5. "Memorandum of Agreement between the Secretary of Transportation and the Secretary of the Army on Permit Processing," 24 March 1980, 45 Federal Register 62771.

6. For further information on the "cooperating agency" role, see the CEQ regulation, 40 CFR 1501.6 and 1508.5.

7. Executive Order 11990, Protection of Wetlands, 24 May 1977, 42 Federal Register 26961, and DOT Order 5660.1A, Preservation of the Nation's Wetlands, 24 August 1978, 43 FR 45285. The wetland orders require a finding that there is no practicable alternative to the use of wetlands and that all practicable measures to minimize harm have been included in the proposal.

8. Urban Systems Research and Engineering, Inc., The Growth Shapers: Land Use Impacts of Infrastructure Investments (CEQ, 1976).

9. Speech by former Secretary of Transportation Brock Adams at the Kennedy School of Government at Harvard University, Cambridge, Massachusetts, 13 February 1979.

THE U.S. EXPERIENCE IN EXAMINING THE ENVIRONMENTAL IMPACTS OF HIGHWAY PROJECTS

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Abstract

An important aspect of any transportation system performance evaluation in the United States is the analysis of its anticipated environmental impact. Using the highway program as a focus, this paper discusses, in general terms, some of the experiences of the Federal Highway Administration in assimilating environmental analysis and impact mitigation into its highway development process.

Following the mandates of environmental legislation, the Federal Highway Administration in 1971 requested each individual state highway agency to develop a written plan which would document how social, economic, and environmental concerns would be given proper consideration in the decisionmaking process. We believe that this individualized approach to the highway development process has been highly successful.

Our experience with social, economic, and environmental issues has confirmed the fact that physical and visible impacts are generally quantifiable, whereas social issues, such as community cohesion and secondary or induced impacts, often defy measurement. The ability to reliably quantify these measureable impacts, such as noise and water quality, has improved to a point where predictions of future impacts are valid. Although quantification of social issues remains elusive, the use of community involvement and citizen participation techniques has been determined to be the most effective method of producing balanced decisions.

Once determined, adverse environmental impacts often require mitigation. Several case examples are discussed which illustrate a wide variety of techniques and project specific solutions that are now being employed on our nation's highway projects.

The final selection of the best alternative for a highway project has been greatly assisted in recent years by sound technical and social analyses which incorporate reasonable mitigation measures. Nevertheless, the final decision is and is expected to remain, complex and difficult.

Introduction

I am most happy to have this opportunity to meet with you and participate in your discussions on transportation system performance. Since this is a very broad subject, my remarks will focus on the effects that environmental considerations have had on the United States highway construction process. This is a subject with which the agency I represent, the Federal Highway Administration (FHWA), has had extensive experience.

More specifically, my remarks will focus on:

- the environmental legislation that has been enacted in the United States;
- the process that we use to assess social, economic, and environmental impacts of highway proposals;
- the public participation process and how it has been expanded to ensure that the views of those most directly affected by a highway project are considered;
- how the planning process has changed to ensure that all reasonable alternatives are examined to avoid social, economic, and environmental impacts.

In the United States, final decisions on Federal-aid highway proposals must be based on a balanced consideration of the environment, needed mobility, safety, and economic development to ensure that our transportation decisions serve community, regional, and national needs and desires.

Transportation agencies in the United States have been trying to balance environmental concerns with transportation needs for many years, long before the National Environmental Policy Act of 1969. While our experiences in trying to give proper recognition to environmental factors will not reveal any simple approach for others to follow, they should give you an understanding of the issues that we have dealt with and some of the frustrations that we have encountered.

Before I get into the matter of environmental impacts, I would like to give you a brief description of how major highway projects are developed in the United States. The Federal Government, through the FHWA, provides funds to the fifty states for the planning, design, and construction of highways. In general, the state and local levels of government operate and maintain the highway systems within their jurisdictions. The states, working with cities and metropolitan planning agencies, are responsible for determining highway needs, selecting and developing projects, overseeing construction, and maintaining the completed highway system. The Federal role is to provide technical and financial assistance and to ensure compliance with applicable Federal laws and regulations. The FHWA monitors statewide and local planning, highway design and construction standards, system continuity, public participation procedures, relocation activities and Federal requirements for protecting the environment. FHWA does this through reviews of state operations and by on-site inspections. The agency also provides technical assistance through research and development, demonstration projects and training courses. In short, the construction of Federal-aid highways is accomplished through a partnership between the states and the Federal Government, a partnership that has been functioning very successfully for the past 65 years.

The majority of our Federal laws requiring the adequate consideration of environmental effects as a part of the Federal decisionmaking process came into existence in the late 1960s and early 1970s. However, the United States has had laws requiring studies of the economic impacts of highway projects for over 30 years, such as the economic impact of highway projects that bypass cities or towns. But the basic framework for conducting environmental studies and thorough consideration of social, economic and environmental impacts was established by the National Environmental Policy Act which was signed into law on January 1, 1970.

The National Environmental Policy Act requires the preparation of an environmental impact statement for each major project that will have a significant impact on the environment. An environmental impact statement is a public disclosure document that discusses the probable impacts of all reasonable alternatives, including the alternative not to build a facility. An environmental impact statement must be circulated to the public and to other government agencies for review and comment before a decision is made on which alternative to pursue. Mitigation measures that will be included in the project to reduce anticipated adverse effects must also be identified in the environmental impact statement. By law, the FHWA is responsible for the contents of the document, but the environmental studies and the actual preparation of the document normally rest with the individual state transportation agency, with active participation by FHWA.

Although the process established to implement the National Environmental Policy Act serves as the backbone for documenting that adequate consideration is given to social, economic, and environmental factors, it is just one of the many laws that have been enacted to protect the environment. Separate laws have been passed to deal with many major environmental subject areas, such as clean air, pure water, noise, and plants and animals that are in danger of becoming extinct. There are also laws to protect properties having historic or prehistoric significance, wild and scenic rivers, wilderness areas, wetlands, public parks, recreational areas, and wildlife and waterfowl refuges.

The list of special environmental legislation is long. Thus, the steps that must be taken to examine the potential social, economic, and environmental issues and to coordinate with the public and private interests on a project-by-project basis can often be very time consuming and expensive.

Some of these laws are very specific and put agencies such as FHWA to a very rigid test. For example, if a proposed highway project would involve the taking of a historic site (this would include the modification or demolition of a bridge that has historic significance), or the taking of land from a public park, recreational area, or wildlife or waterfowl refuge, FHWA must prepare additional documentation. This additional documentation must show that there is no feasible and prudent alternative to the taking of such lands and also that we have included all possible planning in the project to minimize harm to such lands. Another law places limitations on Federal projects that would impact an endangered species or its habitat. The degrees to which these environmental laws must be applied and weighed have been established by judicial decisions rendered by the highest courts in this country.

A good example of an area where the FHWA had to deal with a rigidly imposed environmental requirement occurred when Federal highway traffic noise standards were established. In 1970, the United States Congress mandated the FHWA to issue traffic noise standards for use in the planning and design of Federal-aid highway improvements. At that time, there was little guidance on what to do or how to do it. There were very few people in this country who were knowledgeable on the subjects of measuring and abating highway traffic noise.

Some of the early questions which the agency faced were:

- To what extent should the agency attempt to control noise emissions from the motor vehicle?
- Should noise standards concentrate on protecting interior or exterior activities or both?
- To what extent should the standards attempt to protect future development that might take place on vacant land?
- Should every single noise impact be mitigated?

The agency has focused most of its attention on the mitigation of traffic noise. At one time it was believed that vegetation would provide significant noise reduction. FHWA has since learned that meaningful noise level reductions can only be achieved through the use of very tall and dense vegetation, 100 feet or more in depth. The agency has also learned that noise insulation of buildings can provide a satisfactory interior noise environment. However, because of the millions of buildings adjacent to streets and roads, such insulation cannot be provided for all noise-impacted buildings. Consequently, the agency's participation in noise insulation has been limited to public buildings.

Early in 1970, the agency began to prepare guidelines on how the states should respond to all the Federal environmental requirements then in existence. The agency abandoned the idea of issuing detailed technical requirements for each and every environmental subject area and decided to concentrate on improving the operating procedures of the highway agencies actually responsible for project development. Guidelines were issued that would incorporate environmental concerns into the normal highway planning and project development processes. Under this approach, States were asked to establish their own procedures for:

- identifying environmental effects,
- involving and providing timely information to other government agencies and to the public,

- obtaining the services of environmental specialists,
- using a systematic and interdisciplinary approach, and
- considering alternative courses of action.

In other words, each state developed a written plan documenting how it would ensure that social, economic, and environmental concerns were given proper consideration in the decisionmaking process.

FHWA recognized that it would be necessary to employ personnel with knowledge of and sensitivity to social, economic, and environmental impact identification and mitigation. In addition, it would be necessary to provide additional training for present personnel who were predominantly engineers and whose primary concern had been planning, designing, and constructing highway projects to satisfy existing or anticipated transportation needs. A series of environmental courses, workshops, and conferences were held over a period of several years to demonstrate the importance of social, economic, and environmental concerns in the highway decisionmaking process.

We have found that early coordination with affected Federal, State, and local agencies helps avoid the costly delays and controversy that may occur if significant issues are not recognized and addressed early when the flexibility to respond to them still exists. Early coordination is a key element in each state's project development process.

Over the past 10 to 12 years, the States and the FHWA have developed considerable skills in conducting environmental assessments. Technical specialists, such as sociologists, economists, archeologists, ecologists, historians, and air quality and noise specialists have been added to highway agency staffs.

Although efforts continue toward upgrading the state of the art in nearly all areas, I think we can generally say that we have the greatest success in assessing impacts that are physical and measurable. For example, noise assessment methods are considered to be fairly accurate. For constant speed traffic and for rural areas noise levels can be predicted with some degree of confidence. Also, determining the number of persons displaced by a highway facility is quite straightforward. On the other hand, totally reliable predictive methods have not yet been developed for assessing air quality and ecological impacts. Good techniques exist for measuring baseline conditions, but accurate impact assessments in these areas largely depend upon the analyst's experience and judgment. It is relatively easy to identify the amount and types of wetlands that will be impacted by a particular project. The problem is in trying to determine the significance of the wetlands and the extent of mitigation that should be incorporated into the project.

Impacts that are intangible, such as community cohesion and other circumstances relating to social interaction, must often be assessed in terms of the perceptions of those people directly affected. We have found that the best method to predict social-economic impacts and to evaluate their significance is through interaction with the people most directly affected. Surveys, citizen committees, public meetings, information displays, telephone hotlines, newsletters, and project field reviews involving citizens are some of the techniques used in the United States to identify and quantify these impacts and to develop solutions that will minimize the impacts.

Particularly troublesome, in terms of assessing their magnitude and significance, are secondary impacts such as changes in growth and development patterns or economic and land use activity due to a transportation improvement. Secondary impacts are difficult to forecast because they depend upon actions beyond the control of the transportation agency. Nevertheless, in jurdisdictions that do not have effective land use controls, secondary impacts may be very significant. Energy analyses are also difficult to conduct because of secondary impacts.

Environmental assessments reveal the major differences between alternatives and highlight mitigation measures needed to lessen the adverse impacts expected to result from the selected alternative. Frequently, impacts can be reduced by judiciously replacing parkland, wetlands, and wildlife habitat taken for transportation purposes, or by preserving cultural and historic resources discovered within the right-of-way. Generally, mitigation techniques for specific negative impacts are relatively easy to identify. However, deciding to what extent to mitigate specific impacts is much more difficult. The questions we must answer are: do we attempt to eliminate all impacts regardless of costs or do we balance the good that will result from the project with the expected adverse impacts? In the final analysis, it is the transportation agency that must assume responsibility for making this decision.

An example of unusual mitigation measures involves an interstate highway in the State of Virginia. This project is approximately 10 miles long and passes through urban and suburban developments into the Washington, D.C. Metropolitan Area.

This project is currently under construction, but for years was involved in extensive controversy--legal, public, and governmental.

Initially, an eight-lane freeway design was approved; however, environmental concerns caused the public, local officials, and FHWA to be involved in several court suits. It took nearly six years to resolve the suits, resulting in a restudy of the entire project and additional public involvement.

Ultimately, the Secretary of Transportation approved a four-lane facility with:

- additional overpass structures to improve neighborhood circulation,
- depressed grade line and retaining walls to minimize right-of-way,
- extensive landscaping for a parkway effect,
- noise abatement features (berms and walls),

- prohibition of heavy truck use,
- peak hour traffic limitation to buses and carpools of four persons, and
- hiking and biking trails.

Another example of the need for unusual mitigation measures arose when a highway agency planned a project to cross the watershed of a major reservoir which serves as the water supply for Metropolitan Boston, Massachusetts. Because of concern that the highway would impact the quality of the reservoir during construction and operation of the highway, a series of 35 sedimentation pools will be located adjacent to the highway. The main purpose of these pools is to remove turbidity from surface runoff during construction. Contract provisions also call for the downstream side of the basin to be constructed of pervious stone and sand to act as a filter and access roads to be constructed to all sedimentation pools for maintenance purposes.

Other examples of highway environmental mitigation measures are fish ladders for use during times of low water levels, placement of boulders in streams, construction of deer passages under highway sections, and the building of replacement "wildlife mounds" used by small animals to keep them from burrowing into and damaging the roadbed.

For many projects the key issue is not the magnitude of a particular impact, but the trade-offs that must be made between competing objectives. Some questions are: Should a new highway be routed through a residential area in order to save parkland? Is the public interest served by constructing a bypass that improves the ease and safety of travel but also adversely affects the economic activity of a struggling central city and transfers that activity to prosperous suburban jurisdictions? Can the destruction of a cohesive minority community be justified in order to improve regional access to a hospital? There are no technically correct answers to these questions.

The truth is, the professional transportation planner must try to interpret and mediate the demands of many diverse segments of the public through a process of negotiations. This requires an open process which provides timely information to other agencies and to the public and includes opportunities for interested parties to express their views. The objective is to achieve a community consensus on a course of action that respects the interests of the public as a whole.

Transportation system performance cannot be evaluated solely in terms of the traditional quantifiable measures, such as capacity, level of service, and benefit cost ratios. A project's environmental suitability is balanced against its performance on a broad range of other criteria. The result is not merely functional efficiency, but also a positive return to society from the transportation investment.

Today, with an effective Federal-state-local relationship and close attention to environmental matters, we believe that we are implementing a much needed transportation program with consideration of environmental issues. We are continuing our efforts to fully address environmental factors in our highway development process and through experience and information sharing efforts such as this, we hope to improve our decisionmaking process.

IMPLICATIONS OF UNCERTAINTY FOR ENVIRONMENTAL POLICY

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Abstract

Uncertainty is and will continue to be a major factor influencing the management of transportation organizations. Attitudes toward uncertainty are particularly important in influencing an organization's response to environmental issues.

To respond successfully, transportation organizations must examine themselves and make necessary changes in many important aspects of the organization. This paper presents theoretical concepts useful for such an examination and suggests specific changes in organizational elements and procedures.

Introduction

Objectives

This paper deals with the role of uncertainty and its importance for consideration of environmental issues by transportation organizations and agencies. Particular attention is given to examining what implications uncertainty has for transportation policies and especially for organizational issues. While the primary focus is on public-sector transportation organizations, many of the comments will be applicable to private firms and to organizations in developing, as well as developed, countries.

This paper is an abridgement of the original paper, copies of which are available on request to the author.

Uncertainty and Environmental Concerns

There is a clear and strong linkage between explicit consideration of uncertainty and careful treatment of environmental issues.

In the last fifteen years, a substantial body of research and practical experience has been accumulated about ways to effectively incorporate consideration of environmental issues into the planning and management of transportation facilities and services (see, for example, the extensive coverage in Transportation Research Record). Our own work on community involvement and environmental issues has been based on several principles

(Manheim, 1973; Manheim, 1979, Fundamentals of Transportation Systems Analysis, Volume 1: Basic Concepts, Chapter 14):

Principle I: The Range of Alternatives

The range of alternatives to be analyzed should be sufficiently broad as to represent real choices and should always include the null option.

Principle II: The Identification of Effects

All beneficial and adverse effects of each alternative, whether suggested by past experience, by judgment, by analysis, or by an affected interest, should be fully explored, and the information uncovered should be widely distributed.

Principle III: Involving the Public

Each affected interest, individual, or group must be given ample opportunity to express its views in a timely and constructive manner and thus to influence the course of studies as well as the final actions taken.

Principle IV: Equity

When adverse impacts result for some interest in order that benefits can be provided for others, those adversely impacted should be adequately compensated. Further, the benefits should be distributed broadly.

Principle V: Dealing with Uncertainty

Uncertainties that may exist should be explicitly recognized.

Principle VI: The Decision Process

The process of reaching a decision should be open, participatory, and decisive, resulting in decisions that are implementable and implemented.

These principles have been, directly or indirectly, the foundation for several major Federal policies and extensive actions by State transportation agencies. In 1972, in response to Section 136(b) of the 1970 Federal-Aid Highway Act, the Federal Highway Administration of the United States Department of Transportation issued a regulation, the "Process Guidelines," (FHWA, 1973a). This regulation required each of the 50 State transportation agencies to prepare an "action plan" indicating how it would restructure its organization and administrative procedures to ensure that principles substantially similar to these were implemented fully (for example, by developing internal career ladders for environmentally-trained professionals as well as engineers; cf. Manheim and Suhrbier, 1973, Manheim, Suhrbier, and Bennett, 1972.) The same wording appears in later transit legislation but was not interpreted in the same way by the Urban Mass Transportation Administration.

In 1976, the Urban Mass Transportation Administration promulgated a Policy on Major Mass Transportation Investments (UMTA, 1976a). This policy required any local agency planning to submit a grant application for Federal funding of a major mass transportation project to follow substantially the same principles by conducting an analysis of alternatives (Manheim, Atanucci, et al., 1975). Such "alternatives analyses" are now being conducted in some twenty or more United States metropolitan areas. The same policy was expanded to include highway projects in a recently promulgated Federal regulation (FHWA and UMTA, 1981).

These principles also served as the basis for extensive analyses of organization structure and administrative procedures in a particular State (Manheim et al., 1972), and for a manual published for the American Association of State Highway and Transportation Officials (Manheim, Suhrbier, et al., 1975b).

The role of uncertainty has clearly been recognized in all of this work, as reflected by the fifth principle. For a number of years we felt the most important way of implementing this principle was through emphasis on the process of programming of projects (Reno, Schneideman, and Manheim, 1973; Manheim, 1979b). From this perspective, the major source of uncertainty was whether a particular transportation project would be found environmentally acceptable (or politically acceptable), and therefore, it was desirable to keep implementation priorities open to the last possible moment. This could be best achieved by having a number of projects under development and treating no project as "firm" until an actual decision had been taken to begin implementation. (Technically, under the revised United States planning regulations, the project was eligible for and included in the Annual Element of the Transportation Improvement Program.)

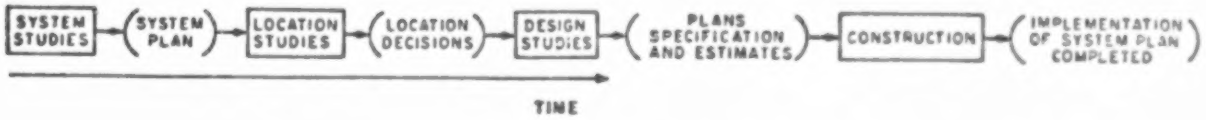
We still feel that the programming process is and should continue to be a key focus for more environmentally-sensitive planning. However, we have also concluded that uncertainty has additional ramifications for the internal organization and procedures of a transportation organization. Therefore, in this paper we focus explicitly on uncertainty and its implications for organizational structure and procedures.

Sources and Effects of Uncertainty

It is clear that uncertainty has become a way of life for managers and decisionmakers in all sectors today. Uncertainty is significant at the international as well as national economic scales; rapid changes in inflation rates, in prices, and in resource availabilities and constraints are major contributors to this uncertainty. While to a certain extent these uncertainties may be attributable to the changed market structure for petroleum products, it seems likely that this uncertainty will continue to exist for the foreseeable future even if inflation rates are brought down to something resembling their more normal values. Compounding these effects are significant uncertainties as to the future growth and evolution of the economic, demographic, and social structure of society.

The effects of uncertainty can perhaps be most clearly visualized by examining a traditional view of transportation planning and implementation. Figure 1 shows the traditional planning and design process which assumed that projects flowed naturally, in a sequence of steps, from initial project conception through system planning studies, location studies, design studies, to construction and then to operation. Most transportation agencies concerned with major infrastructure investment were oriented around this type of process. In the extreme case, each step in the process was assigned to a different organizational element; so, for example, there would be separate groups for preliminary design, for detailed design, for construction, and so forth within the organizational structure. Furthermore, during this period, the dominant style of planning and analysis (at least in rhetoric, if not in actual practice) involved using a comprehensive long-range planning process. In this process, the ideal was that of the classical urban transportation planning process. In this process, a logical step-by-step process was followed. Goals and objectives were formulated, then alternative patterns of land use and social and economic activity were projected, then alternative transportation plans were developed and analyzed, and finally the long-range transportation plan was adopted. Once adopted, it was assumed this plan was a target to be achieved by a year-by-year program of implementation.

FIGURE 1*



***See Manheim et al., 1975**

Unfortunately, neither rigid organizational structure, nor the classical process of long-range comprehensive planning, are well adapted for today's world. For example, if in fact there is significant uncertainty about what a project's cost will actually be when it is ready for bids for construction contracts, or uncertainty about what the actual budget will be in that particular fiscal year, then there is obviously great uncertainty about which projects will be implemented. Neumann and Pecknold (loc. cit.) have shown that if in fact one expected uncertainty, one might well choose other projects more appropriate and different from those one would choose when one assumes the future is certain.

Correspondingly, the transportation operating enterprise, in many countries, had come to expect a relatively stable social and economic environment in which to operate. Because of the complex nature of transportation, operating organizations became complex too with high degrees of functional and spatial differentiation, for example, separation of marketing, operations, maintenance, and other functions. These organizations developed relatively stable professional staffs, highly specialized (whether management or labor), and comfortable well-developed career patterns with predictable if slow paths for upward movement. Of course, organizational structures changed slowly if at all, and significant organizational change tended to be quite rare. The resulting organizations may well have delivered products well tailored to their users' needs at some point in time. However, they were also organizations that because of their stability and specialization had become quite resistant to change.

Implications

In today's world, the only thing that is really certain is that uncertainty will continue to exist and to play a major role in tranportation for a long time to come. Yet, in this era of "certain uncertainty" most transportation organizations are poorly equipped for the challenges they face. For the reasons sketched above, uncertainty is a threat to most organizations.

- People fear change in general and unpredictable change especially.
- People usually rely heavily on stability in their work environments.
- Uncertainty and insecurity can have significant effects in reducing productivity.
- The failure of organizations to be ready to adapt to changing conditions means that major changes in the organization's environment can cause severe disruptions to the organization.

Equally important, an organization that is not comfortable with a rapidly changing and uncertain world will fail to exploit many new opportunities. External changes, while initially perceived as threats, can be turned into opportunity for positive actions (for example, entry into new markets, introduction of new products or services, or measures to improve the efficiency of resource use through organization changes, personnel changes, or changes in management techniques).

Uncertainty can be an opportunity rather than a threat. However, to exploit this opportunity it takes deliberate, planned strategies which recognize:

- the unique nature of the product, transportation;
- the complexity of organizations in the transport sector;

- the unique characteristics of each specific organization;
- the need to build effectively on the existing people and organizational strengths in adapting to new conditions.

Approach

In this paper, we will examine how transportation organizations might respond to an era of "certain uncertainty." We present a conceptual scheme for analyzing an organization's ability to deal with uncertainty (based on Phillip, 1980), and then use this scheme to identify areas of weakness or potential change in typical transportation organizations, suggesting specific steps that might be taken by an organization to help equip itself better.

Our purpose is to illustrate a general approach and way of thinking; it is not to criticize any particular organization or country. Clearly, there will be many organizations which have in fact taken important steps in the directions we suggested here, or may for good and valid reasons reject our arguments or suggested approaches.

In this abridgement, we omit the conceptual framework and turn to a brief summary of the action recommendations.

One key element of the conceptual framework is the identification of a hierarchy of control tasks. The action implications will be summarized in terms of these tasks.

Project Development Process

Intelligence

By intelligence, we mean the process through which individuals or organizations search their environments for conditions calling for the initiation of problem-solving activity leading to the taking of a decision to implement some action (Simon, 1960, quoted by Philip, p. 89). When a transportation organization is operating in a relatively stable world, it has a clear sense of its mission and therefore of the products which it is supposed to deliver. For example, the classic public works organization had as its mission the delivery of implemented highway projects and the continual maintenance of those projects as a satisfactory level of service.

In today's uncertain world, it is unlikely that the intelligence function can be performed in as routine a way as it was in the past. Rather, a transportation organization has to devote a major effort to this function and emphasize the need to monitor significant and uncertain elements in its environment. Some of the activities which are required are described below.

- Monitoring of Trends and Events

  Data collection on a routinized basis should include data on traffic, resource availabilities, and costs--fuel, construction materials, labor, prices, and revenues from all sources; social and demographic trends; and emerging political issues.

  Data analysis on a regular basis and in an insightful and purposeful way should be used to identify problems which might be partially or wholly resolved through transportation system actions, to identify opportunities to intervene in positive ways, to exploit opportunities to advance ideas or proposals which now become timely and relevant at a particular moment. Emily Lloyd suggests the opportunity of exploiting "tailwind" effects by matching a particular transportation measure "to some other trend that is gaining momentum on its own or as the solution for a high-visibility problem" (Lloyd, 1981).

- Reconnaissance Studies

  Occasionally trends may be identified which should be investigated, or problems or opportunities will be identified which should be subjected to some degree of assessment, short of initiating a formal project planning or design effort. A reconnaissance study would be initiated to explore such possibilities as an in-depth intelligence function.

- Study Initiation and Design

  The decision to initiate a study is in itself an important decision. The usual practice in today's world will be to undertake a study only with an open process and with full participation of interest groups potentially affected by the outcome of the study. This means that, as a practical matter, the initiation of a study is in itself a potentially significant policy decision for most non-routine projects. Therefore, the formulation of a study approach will be itself a participatory process (cf. Manheim, 1979, Chapters 14 and 15). Included among the decisions to be made in developing a study design will be: the range of alternatives potentially to be studied; the types of impacts potentially to be analyzed and considered and the organizational structure of the study, including the organization location of the study, the disciplinary composition of the study team, the technical methods to be utilized, including data sources and degrees of formal modelling, and the process for timely constructive involvement of affected interests (cf. FHWA, 1973; FHWA and UMTA, 1980).

Note that this description of tasks explicitly presumes that every study is likely to be different. In other words, the planning and design studies of the transportation organization cannot be cast in a single mold.

Search

The search activities are what good planners or designers have always done: develop, design, and synthesize creative actions and strategies. Particular emphasis must be placed on developing action proposals which are flexible in the face of uncertainty. This means, for example:

- staged strategies, with actions proposed for different points in time;
- conditional strategies, with alternative actions proposed for future years with the alternative to be selected contingent on future events;
- actions which will work well over a wide range of future conditions and will be robust in the face of uncertainty.

As a consequence, much attention will be given to smaller projects which may or may not culminate into grand plans, but which will work well even if related projects never get built.

Prediction

Prediction is the act of estimating the likely effects of one or more action proposals. The choice of technical methods is especially important in an age of uncertainty. This comprehends several major issues including choice of prediction procedures and how they are developed and used and choice of evaluation methods. Several actions which can be taken (detailed in the full paper) include: the use of sensitivity analyses, the use of explicit scenarios, and the use of multiple models at multiple levels of detail (Manheim et al., 1980; Kocur et al., 1977; Manheim 1966). (For comments on evaluation and choice procedures, see the original paper.)

Program Management Process

As described earlier, in the early days of development of a major infrastructure system (such as a system of highways), the mission of an agency is seen as "to complete the system." In this context, each project is expected to move in a relatively routine way through the successive phases of its development, culminating in implementation. In the era of certain uncertainty, it is always uncertain whether a particular project will be implemented, or when, until construction actually begins. Therefore, top management must always have more options to chose from than could likely be implemented. Thus, there becomes the need to manage a program of project development activities whose outcome is highly uncertain, and in which multiple options are to be available for agency decisionmakers. Such a program includes studies and project development activities for many more projects than can ever be implemented.

An overall conceptual framework for such a process has been described in detail elsewhere (Manheim, 1979b). To summarize, such a process should have these features:

Programmatic - The basic management tool is a multi-year program plan (MYPP). This consists of a program of actions staged over a number of periods (1 to 15 or 25 years in a public works agency, 1 quarter to 5 or 10 years in a transportation enterprise). The first period of the plan is firm and detailed: it is the set of specific implementable actions which will be taken in the next period. Each succeeding period of the plan is less firm and less detailed. This MYPP contains all significant projects, including studies--planning, location and design activities, monitoring, reconnaissance, evaluation and research activities, as well as construction or other forms of implementation activities. The MYPP can and should show explicitly where decisions on actions to be taken in future years have not been made, or are contingent on the outcomes of earlier actions (for example, whether a facility will be built as two or four lanes is contingent upon the outcome of a future study or on the level of traffic reached on a nearby facility in a specific year).

Periodic - The MYPP is reviewed annually (or on another regular schedule) and revised in an explicit decision process. This decision process results in moving some projects forward in their development, slowing down, delaying, or cancelling other projects, and putting new projects on the table for future consideration.

Planning-informed - Planning studies, as well as other kinds of studies, are useful in informing the process of making programming decisions by:

- assessing the mid-range and long-range consequences of near-term actions;
- assessing which alternative future options are left open, and which foreclosed, by specific actions being considered now for implementation soon;
- exploring alternative views of the system's future state and alternative stagings of actions over a number of years into the future (Manheim, 1979, p. 328).

Performance-oriented - Results actually achieved are determined and assessed explicitly, through monitoring of the effects of project implementations, and analysis of actual versus predicted effects, in light of continually changing exogenous conditions as well as the actions of the agency.

Professionally-responsible - Alternative multi-year program plans are developed and analyzed in each decision cycle and there is open discussion of the alternative programs and the key issues and trade-offs which should be considered by decisionmakers and other interested parties in reaching a choice on a MYPP to be adopted. The annual cycle of activities includes development of alternative MYPPs, identification of the effects of the alternative programs (which are often different from the sum of the effects of the projects in the program), and timely involvement of affected interest groups including the public.

This kind of process recognizes uncertainty explicitly. The periodic nature of the process, together with periodic assessment of accomplishments and failures, and of changes in uncontrollable variables, is essential in dealing effectively with uncertainty.

Specific features to highlight in this image are role-played by:

Monitoring and evaluation (cf. Meyer, 1980) - As discussed in the section entitled "Intelligence."

Information systems - For example, management systems to keep current information on the status of agency costs, expenditures, revenues, workloads, etc., and, especially important, to predict monthly, quarterly, and annually the future values of these factors. Uncertainty and high inflation both require tight control on fiscal resources and the triggering of management reappraisals of prior decisions under appropriate circumstances.

Explicit design of the annual cycle of analyses and decisions - These will be different in different cultures. Some situations may support highly-structured explicit decisions annually on a program which then proceeds expeditiously toward implementation. Other cultures may resist (for example, Gakenheimer and Keller, 1980).

Organization Direction-Setting and Organization Development Strategies

In the era of sequential process, the control of the organization's operations meant the specific management of each separate functional unit in the organization and the management of the flow of work from each unit to the next. In the era of certain uncertainty, operations management is a much more complex task. Work assignments and priorities change much more frequently at each level of the organization and in each functional area as each organizational element monitors its environment and adapts to the changing conditions.

The adjustment of the organization to the era of certain uncertainty may require deep and far reaching changes. To illustrate:

- A major shift in resources may result in certain professional skills no longer being essential; how will these individuals react? Will they adapt willingly to the need to acquire new skills again in order to continue to play some useful role in the organization?
- A shift in priorities may cause a particular project to suddenly shift from high-priority to "very unlikely to ever be implemented." If a

professional has spent two to four years on that project, how will his morale be affected? How will individuals see their promotion and career advancement opportunities affected by events beyond their control?

- If the results of technical analyses are highly sensitive to the choice of scenario assumed, will professionals feel that technical analysis is essentially irrelevant? How will this reflect on their perceptions of themselves, their jobs, and their role in the agency?

Conclusions

While this analysis has been more suggestive than thorough, the major conclusions are clear.

- To operate successfully in an era of certain uncertainty, transportation organizations must examine themselves and make necessary changes in many important elements of the organization.
- The conceptual framework presented in this paper (the control task hierarchy, the organization support system, consisting of organizational structure, information system, and decision processes) are useful in helping to diagnose an organization and examine its ability to operate in this new environment.
- A number of specific suggestions can be made for organizational and procedural changes.

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A DIRECT APPROACH TO THE EVALUATION OF AIR POLLUTION GENERATED BY MOTOR VEHICLES IN THE FEDERAL REPUBLIC OF GERMANY

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Abstract

Relevant discussions about air pollution and its effects on human beings are still very wide ranging.[1] Planning, developing, and extending traffic infrastructures require not only that changes in exposure to pollution be considered but also that valuation methods which are suitable for practical application be established.

Due to the prevailing uncertainties about the health effects of pollutants, economic valuations generally have not been based on actual health damages but rather on the costs of controlling such effects.[2]

In the model described in this paper, a valuation method is presented to attempt to assess the real economic losses due to exposure to pollution.

Preliminary Remarks

It is true that relevant discussions about air pollution and its effects on human beings are still very wide ranging.[1] Nevertheless, planning, developing, and extending traffic infrastructure require not only that changes in exposure to pollution be considered, but also that valuation methods which are suitable for practical application be established.

Largely because of the prevailing uncertainties about the health effects of pollutants, economic valuations generally have not been based on actual health damages but rather on the costs of controlling such effects.[2]

However, with respect to the evaluation of automotive emission, the costs-of control approach involves some definite drawbacks:

- In the case of pollution control measures, in contrast to traffic noise countermeasures, one starts with the car itself, but cost allocation by area is no easy matter. However, it is possible to make a cost distribution based on vehicle-kilometers by evaluating the total of vehicle-kilometers per unit of time and section of road. This leaves the question of how to measure the pollution burden on affected residents. Another question is the level of exhaust reduction to be considered in the assessment (for example, 20%, 40%, or even 80%) for it is clear that technically it will not be possible to vary control features to fit local reduction requirements. For example, a standard for the legal exhaust level reduction may be established for the road section considered as the most critical, from the points of view of traffic, vehicle parameters, and meteorological conditions. This would result in considerable expense for emissions control in all motor vehicles whether they ever actually occupy the section of the road in question. Basing control measures on a mean reduction level would not ensure compliance with threshold exposures everywhere.

- Even if one were to assume that these difficulties might be overcome, it should not be overlooked that the costs of control and real damages to be identified essentially represent two different types of costs which can only be brought into conformity by means of extensive assumptions regarding society's "willingness to pay." The simple story of the leaking barrel of poison, in which inestimable damage can be prevented at negligible expense, is a case in point.

In the following model description, a valuation method is presented to attempt to assess the real economic losses due to exposure to pollution. This method will be part of the RAS-W[3] report which is in preparation and will be applied before long.

The Model

On the basis of epidemiological studies on respiratory diseases in the United States, Ridker and Lave/Seskin,[4] whose work is still of relevance for the problem dealt with in this context,[5] established the hypothesis that global air pollutants, such as SO_2 and particulate matter (smoke, dust), are responsible for causing 20% (Ridker) and/or 50% (Lave/Seskin) of these diseases. On the basis of temporary or permanent work disability, the quantitative share of pollution-induced diseases can be converted into costs. In addition, proportional shares of costs for medical treatments, drugs, and therapeutic aids must be considered. If the sum of these costs is brought into relation to the emission of SO_2 and particulate matter, which are considered to be the cause and which are made comparable to one another by means of toxicity factors[6] derived from their threshold levels, the results are costs per ton of emission (the so-called proportionality factor). (See Table 1)

TABLE 1

THRESHOLD EXPOSURES AND CORRESPONDING TOXICITY FACTORS

Pollutant	Threshold Exposures in mg/m^3		Toxicity Factor
	Long-term	Short-term	
SO_2	0.12		83
CO	10		1
CH		0.29	103
NO_2	0.10		100
Particulate matter	0.10		100
Pb	0.001		10,000

To apply this measure to the assessment of exhaust emissions, it is necessary to assume that if a causal relationship exists between global air pollution and respiratory diseases, the same relationship holds true for local concentrations of polluting agents as well. It is then possible to apply the cost per ton of emission, estimated on the basis of the global hypothesis, to the air pollution generated by motor vehicles. Different pollutants, in this case also, are made comparable to one another by means of the toxicity factors shown above.

Finally, the resultant costs can be distributed throughout the total population of those affected by automobile-generated air pollution in the Federal Republic of Germany.

Global Air Pollution and Respiratory Diseases in the Federal Republic of Germany in 1980

Total Emission

The sum of SO_2, particulate matter, and NO_2 emissions[7] is a measure of general air pollution. According to the Federal Environmental Agency, the following emission quantities were recorded in 1980: 4.1 million tons of SO_2, 0.5 million tons of dust, 2.3 million tons of NO_2.[8]

Economic Consequences of Respiratory Diseases

Estimates of the working time lost because of respiratory diseases (malignant tumors, asthma, and bronchial and other respiratory diseases, but not tuberculosis) and of the medical treatment, drugs, and therapeutic aids required therewith are suitable initial data for an economic valuation of the damages to human health. For that reason, a set of quantities comprising sick leave, hospitalization, medical treatment, and partial or permanent work disability due to the diseases mentioned is established.

Mortality has not been considered because, on average, the people dying from the diseases dealt with in this context are past the age of 65[9] and the economic worth of people in this age group still is a controversial matter.

Sick leave data about the types of illnesses involved are provided from health insurance statistics.[10] Temporary disability for work is assessed on this basis.

The assessment of permanent and total work disability can be based on well-structured data, provided annually, which covers new pension recipients disabled by certain diseases.[11]

A set of values for sick leave, hospitalization days, illnesses (to account for the costs of medical treatment), vocational disability allowances, and invalidity pensions in the Federal Republic of Germany for 1980 is represented in Table 2 below.

TABLE 2

TEMPORARY AND PERMANENT DISABILITY FOR WORK AND MEDICAL TREATMENT

	Sick Leave	Hospitalization	Cases of Illness	New Disablement Pension Cases because of:	
Type of Illness	In millions of days	In millions of days	In millions of cases	Vocational Disability	Invalidity
Malignant Tumors	0.5	0.8	0.02	140	2,041
Asthma Bronchial Diseases	1.2	0.9	0.05	201	1,401
Other Respiratory Diseases (except Tuberculosis)	54.1	10.3	4.2	1,486	10,886

The monetary value of sick leave is based on the net national product at factor costs (= national income) per average employed person and working day. For 1980 it is estimated at DM 221.[12]

The monetary value of hospitalization is based on the hospital allowance granted by the insurance companies to cover general ward costs. In 1980 it was in the DM 170 per day range.

The costs of medical care are estimated at DM 52 per case. With drugs and other therapeutic aids required during the period of treatment, the costs go up to DM 92 per case.

To conclude, the permanent economic costs due to premature vocational disability and invalidity are assessed for the period from the initial date of pension payment to the normal retirement age (65 years for men and 60 years for women). In this case too, evaluation is based on the national income per average employed person. An annual growth rate of 6.3% is factored in and the resultant sum discounted at a rate of 3.5% to provide the figures for the reference year 1980. Calculations based on national income are preferred over those based on pension payments because the proportional share caused by voluntary reductions in consumption, due to past social insurance contributions, and various other redistribution components must be taken into consideration, whereas what is sought in this context is data about the magnitude of the real economic loss. The resultant pension costs are charged in full to the year of initial pension payment (1980). This procedure might be objected to on the grounds that vocational disability and invalidity should be considered as resulting from a cumulative process of recurrent illnesses which, in part, began long ago. However, in the long run, a balance for pension costs is achieved because costs are ascribed to the reference year, 1980, and do not enter the calculations for any of the years thereafter. The assessment is represented on Table 3.

If, according to Ridker, 20% of these costs is chargeable to global air pollution, the costs amount to DM 4,543 billion. Based on the global emission estimates of 620.3 million tons per year, the damages in Germany in 1980 amount to DM 7.30 per ton of weighted emissions. The evaluation of automotive emission given below is based on this rate.

Assessment of Automotive Emission Inside Urban Areas in the Federal Republic of Germany

Automotive emission is computed on the basis of both vehicle-kilometers inside urban areas and specific emissions (in this case: emissions per vehicle-kilometer).

TABLE 3

SUM OF COSTS GROUPED ACCORDING TO COST TYPES AND TYPES OF DISEASES IN THE FEDERAL REPUBLIC OF GERMANY (IN MILLIONS OF DM--1980 PRICES)

Type of Illness	Costs for Sick Leave	Costs for Hospitalization	Costs for Medical Treatment	Vocational Disablement Pensions	Invalidity Pensions	Sum Total
Malignant Growth	110.5	136.0	1.8	47.5	1,056.6	
Asthma Bronchial Diseases	265.2	153.0	4.6	86.5	587.8	
Other Respiratory Diseases (except Tuberculosis)	11,956.1	1,751.0	386.4	241.9	5,932.0	
Sum	12,331.8	2.040.0	392.8	375.9	7,576.4	22,716.9

Vehicle-kilometers

The difficulties involved in assessing vehicle-kilometers are common knowledge.[13] This study is based on the DIW figures for 1977[14] and results in 85.5 billion vehicle-kilometers inside urban areas for passenger cars and 9.5 billion vehicle-kilometers inside urban areas for trucks, buses, tractor-trailer combinations, and tractor-trucks.

Distribution of Vehicle-kilometers Based on Different Modes of Operation

Apart from the type of car, specific exhaust emissions also depend on the mode of operation (stationary, acceleration, constant speed, deceleration). The percentage for each mode varies widely in urban traffic. The potentially wide range of operational modes has been narrowed down by the Technical Inspection Board (Rhineland)[15] to seven standardized operational cycles or modes which are characterized by a mean driving speed and by which the share of each operational mode can be accurately determined for any distance travelled. Their range of application includes the CBD's ringroads or bypasses and the outskirts.[16]

The distribution of vehicle-kilometers inside urban areas, based on these operational modes, was determined for conurbations in the Federal Republic of Germany in connection with the development of Air Quality Programs.[17]

By means of this distribution scheme, the same determination has since been carried out for all vehicle-kilometers inside urban areas in the Federal Republic of Germany (See Table 4).

TABLE 4

DISTRIBUTION, BASED ON OPERATIONAL MODES, OF THE TOTAL OF VEHICLE-KILOMETERS INSIDE URBAN AREAS

		Passenger Cars		Trucks	
Mode	Mean Speed in km/h	Percent of all Vehicles	Vehicle kms in Billions	Percent of all Vehicles	Vehicle kms in Billions
0	19.5	3.4	2.9	1.9	0.2
1	100 constant	24.9	21.3	40.6	3.9
2	60	12.0	10.3	12.1	1.1
3	42.5	34.5	29.5	30.7	2.9
4	26.0	24.6	21.5	14.4	1.4
5	13.5	0.5	----	0.3	----
6	6	0.1	----	----	----
Sum	----	100	85.5	100	9.5

Assessment of Automotive Emission Inside Urban Areas

The vehicle-kilometers in Table 4 are multiplied by a specific emission factor assigned to each operational mode. These emission factors, which define the quantity of exhaust gas emitted per reference unit (in this case per vehicle-kilometer) within one of the operational modes, were established by the Technical Inspection Board (Rhineland) in 1970[18] and are based on an examination of a cross-section of the car population in the Federal Republic of Germany for that year. The factors were updated in 1975[19] and projected for 1981 taking into account existing and projected legal exhaust standards.[20] An application of the projected 1981 figures to passenger car and truck-kilometers in use inside urban areas led to the following automotive emission figures for the Federal Republic of Germany for 1980:

CO = 1,583,390

SO_2 = 16,190

NO_x = 211,954

CH = 182,231

Pb = 1,254

Soot = 4,478

In accordance with specified procedures, these emissions have to be weighted by means of their relative toxicities prior to assessment made by using the proportionality factor. The resultant total emissions for 1980 are thus estimated at 55,880,153 tons.

Evaluation of Automotive Emission and Associated Damages

The total of emitted pollutants, which are made comparable by means of the toxicity factors, is now assessed by means of the proportionality factor (= DM 7.30/ton). The economic damage caused by automotive emissions amounts thus to DM 409.4 million per year.

This amount, which includes all pollutants from automotive emissions, can be distributed throughout the population affected by it. Persons affected are those exposed to a quantity of CO emission which exceeds half the long-term threshold exposure laid down in TA-Luft.

Because of variations in the total burden per single case, a conversion to population equivalents has been made. One population equivalent has been defined as a person suffering threshold exposure. Based on this criterion, the number of population equivalents in the Federal Republic of Germany has been estimated at approximately five million.[21]

The damage caused by exposure to automotive emissions is thus estimated at about DM 80 per population equivalent and per year.

In a specific planning case, what is left to be done is to analyze the local situation in terms of exposure to CO, to obtain the number of affected persons in terms of population equivalents, and to multiply these by the damage quantified above to project the emission damage to be expected from the planning alternative under study.

Concluding Remarks

However, the procedure presented has its limits, and the following comments need to be made once more:

- The demand for factoring in automotive emissions in road construction projects is established, particularly in terms of a rational utilization of national economic resources.

- The assumption that air pollution has a share in causing certain diseases is certainly a matter to which a final answer has yet to be found. For that reason, Ridker's conservative estimate (20%) has been used. However, it is quite safe to say that noticeable effects must be expected. The threshold levels existing for all pollutants make this quite clear.

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20. Ministerium fur Arbeit, Gesundheit und Soziales des Landes NRW (Hrsg.), Luftreinhalteplan Ruhrgebiet Ost 1979-83, Düsseldorf 1979, pp. 247-; Luftreinhalteplan Ruhrgebiet West 1978-82, Düsseldorf 1977, p. 316.

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ENVIRONMENTAL IMPACT ANALYSIS IS A PRICING PROCESS

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Abstract

The objective of transportation investments is environmental impact, that is, the improvement of an existing land use or the shift from one land use to another. Therefore, transportation investments automatically impact the land uses they are designed to serve. But they also impact the land uses through which they pass. Some of these transportation impacts are objectionable because they represent the "taking" of goods of one of two kinds: 1) the taking of real property, such as homes, business, the shift of land from park uses to transportation uses, and 2) consequential damages where there is no transfer of title but a taking of value, such as damage to a vista, an historic district, a home site, a commercial market area, or a neighborhood. Such environmental impacts are transportation costs. Where these costs cannot be paid for in full, or eliminated, the transportation investment should never be made.

However, under the rules of the U.S. Highway Acts from 1956 until 1970, full value could not, by law, be paid for certain goods taken by Federally-financed projects. Where interstate freeways have been built or planned through dense urban areas or in valued natural landscapes, the difference between actual costs and the total costs carried on project budgets has been large. Resistance to these projects, by the people affected, has also been large.

Later highway and transportation acts, and other statutes, have made it possible once again to use Federal money to pay for those transportation construction costs we call "environmental impacts." To understand the state-of-the-art of surface transportation construction and operation it is important to understand the effect of these statutes on the transportation investment process.

Introduction

It is the objective of transportation system construction to transform the environment, and it is the purpose of transportation system improvements to make the environment more useful. Because transportation systems provide access to markets, prairies are changed into cornfields and mountainsides are changed into open pit mines. Because transportation systems connect home sites with work sites, cornfields are changed into subdivisions, rural crossroads are changed into shopping centers and quiet town centers become clusters of dense, high office buildings. People who would argue that transportation systems should have no impact on the environment are not only being unrealistic, they misunderstand the purpose of transportation investments.

Apart from their purpose of changing the way certain natural and manmade landscapes are used, transportation systems have side effects both on those places they are designed to serve and on those landscapes through which they pass. Those changes are often damaging to each environment; they affect the environment during construction and they rather automatically affect the environment during the entire life of each system. Such short and long term damages are what is generally meant by "environmental impact," and this is one of the two ways that term will be used in this discussion.

But more often than even most transportation planners realize the secondary effects of transportation systems are benign, and occasionally system elements are high art. Railroad stations, air terminals, even subway stations provide monumental entrances to cities; people become sentimentally attached to the appearance and even the sounds of roads and railroads in the rural landscape; city streets not only control the distribution of urban activities but well-designed and well-managed streets can be more important to the architectural quality of cities than is the design of the buildings to which they provide access.

So to determine the state of the art of transportation system impact, two sets of questions should be asked:

1. Are the potential damages created by the construction and operation of transportation systems being eliminated? If these damages are not eliminated, are those people who are damaged compensated for their damages?

2. Are the environmental possibilities of transportation system improvements being exploited? Are transportation investments made in such a way that both transportation and environment are improved?

Environmental Impact and the Highway Act of 1956

In America the perception of "environmental impact" as a transportation construction problem began as a reaction to the urban extensions and to certain mountain segments of the Interstate Highway System. The system was originally planned to skirt the cities, and the urban extensions were included partly to assure the support of big city mayors in pushing the 1956 National System of Interstate and Defense Highways Act through the Congress. When the 1956 Act was passed, enormous amounts of Federal money became available for highway building, and the authors of the early Highway Acts were concerned that these public funds be allocated efficiently. The Congress required cost/benefit analysis to support highway investments and allocated money for the area transportation studies on which such analysis must be based, and the rules for payment for expropriated property and other damages were set at the minimum permitted by the Constitution.

Because the interstate highways were paid for 90 % by the Federal Government and 10 % by the State governments, the urban interstates were seen by city governments as windfalls. But by the early 1960s the first sections were built and in operation; the reaction of part of the public to highway construction changed. The reasons for this change were summarized in 1970:

> Since land costs are a major part of urban highway costs, the early urban interstate expressways found their way into public lands and into poor residential districts. Because much of the public land used was park land, this created opposition among park lovers. Because displaced slum dwellers often had no place to go, this raised the opposition of the socially concerned. Because many of the finest American historic buildings are located in the older and more delapidated parts of cities, the early urban expressways often did violence to historic buildings and districts. This insured the opposition of historicists. The reaction was predictable: coalitions of pressure groups in various cities challenged highway construction. And because these pioneering urban expressways were built by state highway departments experienced primarily with rural expressways, often over the opposition of city planning departments which in turn had little expertise in highway planning, the marriage of city and highway was seldom idyllic.[1]

The engineering and urban design professions and the Bureau of Public Roads (BPR is now called the Federal Highway Administration) responded in a number of ways. The Bureau in one of its Policy and Procedure Memoranda (BPRPPM 20-8) instructed all consultants and agencies working on interstate projects to study 23 different specific "effects" of highway construction. In an explicit recognition of the fact that city change and transportation investments are two sides of the same coin, the Bureau announced a policy of "joint development" of urban highways and the neighborhoods through which they pass. Because highway building in a complex landscape requires many skills besides highway engineering, "design teams" were seen by some as an answer to urban highway building problems. A number of teams were formed; the two largest, in Chicago and Baltimore, included architects, movie makers, landscape architects, urban designers, economists, market analysts, sociologists, and a variety of engineers--in short, the full spectrum of Platonic Guardians.

But while BPRPPM 20-8 recognized that environmental impact was not a generalized problem, but a series of particular "site specific" issues, it provided only a checklist by which issues could be catalogued and then ignored. "Joint development" was an official recognition of the essential purpose of transportation investments, but the money for highway construction was never matched by money for urban development. The major design teams produced imaginative, even eloquent designs; but the work of one has been largely rejected and much of the work of the other is still in litigation.

Environmental Impact and American Law

Each of these actions by the highway building agencies responded to an aspect of environmental impact, but none addressed directly the underlying issue. It is the central problem that in any large public investment there is, automatically, a "taking" or a transfer of goods from one sector of society to another. This transfer, which is often forced on the individuals and communities whose goods are taken by governments for public purposes, takes two forms:

- expropriation of real property, and
- consequential damages, the legal term for negative impact where there is no transfer of title but where there is a taking of value.

Many private actions have similar effects. Transfer of title must take place under well-defined rules; there must coexist the economists' "willing buyer" and a "willing seller." But even the earliest economists recognized inequities in the market process. Economists call consequential damages "externalities;" the environmentalists use the more vivid term, "downstream effects." The people whose goods are diminished by either public or private action, without adequate payment, use even more vivid language and they cannot be expected to favor those actions. When the actions are very large and many people are affected, as when an urban expressway is built, the political opposition will automatically be very large.

So to understand the environmental impact of surface transportation systems we must first define "goods" and then ask under what conditions either public or private agencies can properly take goods from one sector of society and award them to another. While highways will be used as examples, the conclusions apply to other transportation systems, to urban renewal projects, to improvements in rivers and harbors and to almost all types of mining operations, that is, to all enterprises with large effects on the urban and natural environment.

While these problems are now modern in scale, they are very ancient. Nero wrote no environmental impact statements, but Pope Pius V, when he cleared way for Cleopatra's Needle, followed rules more exacting and more precisely articulated than those followed by urban planners and highway engineers in America in the 1960s.[2]

In America the Just Compensation Clause of the Constitution states that the public may expropriate private property for public purposes. But while it requires, it does not define just compensation. Construction of the new, nineteenth century surface transportation system, the railroads, demanded such a definition. The rules for compensation were codified in a series of court decisions leading, in 1893, to Monongahela Naval Company versus the United States. In the Monongahela decision the United States Supreme Court announced that "...just compensation, it will be noted, is for the property and not to the owner." In short, the value of property for purposes of compensation in expropriation cases could be determined independently of the views of the owner. This is the legal underpinning for the "fair market value" basis of payment for expropriated real property.

Even in 1893 the fair market value premise was recognized to be unfair. It abrogates the market and adopts a value assumption that would not be accepted, in America, in any elementary economics seminar. The phrase "burdens of common citizenship" was coined to gloss over its inequities, probably by those who knew the burdens would be borne by others.

A decade later, in Earle versus the State of Massachusetts, the State Supreme Court ruled that Massachusetts could pay for damages beyond "fair market value" to the owners of private land taken for public reservoirs. Oliver Wendell Holmes, then Massachusetts Chief Justice, spoke of the inequities of the Monongahela decision in his much quoted opinion in the Earle case: "It is not forbidden to be just where it is not required to be under the paramount law." The Monongahela decision established a statutory condition for just compensation; the Earle decision established this as a minimum, but not necessarily sufficient, condition.

Both the Monongahela and Earle decisions addressed the taking of real property. What is now called environmental impact is often a consequence of such taking, but it often goes beyond the taking of real property to include consequential damages. These damages are sometimes described as dealing with "intangible values." This is a curious phrase, because it almost always refers to goods that can be seen, heard, smelled, or touched.

Both the definitive analysis of environmental impact due to public actions and an outline of the proper American response to such impact is found in "Property, Utility, Fairness: Comments on the Ethical Foundations of 'Just Compensation Law'" by Frank I. Mickelman, in the April 1967 issue of the Harvard Law Review.[3] Because Mickelman is interested in taking, he first defines "goods" as "...all of these land uses are part of society's sum total of goods: the foundry manufactures are such goods; so is household shelter; so is a neighborhood gathering or play space; so is the serenity that emanates from a quiet, shaded street."

Mickelman goes on to take the conventional position that a government can properly take private goods when "...the society is acting rationally in the sense that the new condition of resource employment will produce a greater amount of 'welfare' than the old one did...," and he defines a "greater amount of welfare" by efficiency tests, defining a proposed change as efficient if "...after negotiated compensation has been promised by those who stand to gain from the proposal to those who stand to lose from the proposal, the proposal can win unanimous approval." He recognizes that unanimity is a goal that can be approached but never attained, but he also recognizes that the principle of unanimity is the foundation, in practice, of "just compensation."

That is the position held in this paper. It is an austere and demanding position, about which questions must be asked regarding transportation systems and their environments. What would be the practical consequences of honoring, rigorously, the "just compensation" objective? What must transportation building and operating agencies do to implement such a policy? Do current changes in transportation policy and practice aim at "just compensation" for those injured by transportation impacts?

In fact, many elements of surface transportation systems have been built, before 1956, to these criteria. During the last decade a number of changes have been made in Federal legislation that make "just compensation" by Mickelman's definition a mandatory objective in the construction and operation of projects using Federal funds. The consequences for surface transportation system performance are beginning to be apparent.

Some Examples of the Environmental Impact of Freeways Built Before 1956

A favorite urban highway case history, at least among a few people interested in the impact of surface transportation systems on the environment, was published in an April 1941 issue of The New Yorker Magazine under the title "A Reporter at Large: Through Thick and Thin."[4] It is the story of the planning and construction of the East River (now the FDR) Drive, through what certainly was one of the most difficult urban highway corridors in this country.

This grade-separated, limited-access freeway was designed by civil engineers and landscape architects working for the New York City Department of Public Works. A photograph was taken of every property and every community amenity to be taken by the highway. Commissioner Binger then met with each individual and community group that would be affected by the road. Probably every type of environmental and community impact later created by the urban extensions of the interstate system was likely to be a consequence of the construction of the East River Drive. Over drawings of the road and photographs of the property these problems were resolved jointly, by the community and the engineers, in a number of common sense ways. For instance:

- The road was tunneled under Gracie Mansion, the fine early nineteenth century structure that is the residence of New York's mayors.

- Two acres were added and a new esplanade built at Carl Schurz Park--a reasonable payment for the inconvenience created during construction.

- Pedestrian overpasses reconstituted access to the river's edge and created a number of new access points.

- In the industrial section conveyors carried goods over the new highway from unloading docks to warehouses and factories.

- When Miss Anne Morgan rebelled because her six plane trees were to be taken, the highway alignment was wiggled enough to save five trees; she was given two Japanese maples in return for the sixth.

- The only house taken was rebuilt, brick by brick, over the highway, where it still stands.

Questions of "air rights" never arose; the highway builders took what they needed: a tunnel of space through the city. Commissioner Binger announced that the original owners would retain everything from the highway to heaven; the City would own everything from the highway to hell. The drive was festooned with joint development 25 years before that phrase was invented. The New Yorker reported that little old ladies (probably in tennis shoes) painted water colors of the highway construction and served afternoon tea to the engineers.

Community reaction to interstate highway construction has been very different. Across the river the Brooklyn Heights Expressway (the only highway on the National Register of Historic Building) had an even more positive environmental impact. Two directions of traffic, plus a pedestrian esplanade, were terraced into the escarpment overlooking the industrial waterfront below. The consequences of the design were these:

- Industry was provided with good access from the arterial street at grade level; arterial traffic is separated from through traffic and from the residential neighborhoods above.

- Through traffic is carried past both industry and residences; overhanging travelways and esplanade above shield the homes from traffic noise and, to a certain extent, from air pollution.

- Two rows of fine, historic residences running the entire length of the escarpment would have been taken by a conventional design; these are still standing, now enormously valuable.

- A spectacular esplanade was added to the residential neighborhood.

During the period when these and other fine urban freeways were being built, handsome grade separated, limited access freeways were also being constructed through rural and mountainous terrain. The Blue Ridge Parkway, for instance, was started before the Second World War by the National Park

Service; it traverses some of the loveliest and most jealously guarded landscape in the eastern United States. Designed by the Region 15 office of the Federal Highway Administration, it is just now being finished. The Linn Cove viaduct is particularly elegant; its construction is disturbing the land only within a few feet of its piers. It is built with erection trusses and the Parkway serves as its own construction road.

The careful cost accounting required by the Federal Highway Administration has been criticized by many people concerned about the environmental impact of highways. But any American who, in 1981, does not believe that public investments should be subjected to efficiency tests must be mad. Accompanied by a healthy skepticism over public cost accounting methods, arguments for cost benefit tests seem unassailable. The problems have not come from the requirements, but from the fact that the accounts have been inaccurately calculated. By 1970 it had become apparent that, even when aggregate accounts were favorable, the costs and benefits of the urban interstate extensions were unevenly distributed, and often those who had the least to gain suffered the biggest losses. Because the costs were borne by private groups and individuals, rather than carried on project accounts, the cost side of the equations were often wildly inaccurate.

In simpler terms, the early New York freeways, the fine suburban and rural parkways were embraced by their communities because they were built under the rules of the Earle decision; the urban extensions of the interstate system were rejected because they were built under Monongahela rules. Because the economic and philosophic underpinnings of these public investments were in disarray, they became politically unacceptable. A public policy outcome, beginning in the late 1960s, was the present continuing Federal concern with the environmental impact of surface transportation systems.

The Environmental Impact of Highways Built Since 1970

The remaining unbuilt sections of the interstate system are, generally, the most environmentally difficult parts of the system. One way of assessing the consequences of this legislation, and the "state-of-the-art" of the impact of transportation systems on the environment, is to examine these unbuilt sections. Table 1 summarizes the status, as of 1979, of the "gap sections" remaining to be completed and lists the reason for their delay. Selected, particularly difficult sections are described in more detail.

All of the opposition to these sections, except "dollar cost," is opposition for environmental reasons, as broadly defined in this discussion. The 91 projects are a total of 830 miles long; total cost is estimated at $12,800,000,000, an average cost of $15,400,000 per mile. Of these 91 projects 20 have been approved for construction; State governors have requested that 11 be withdrawn from the interstate system. The funds allocated for these 11 sections will be shifted to other transportation projects within each state.

TABLE 1

UNFINISHED GAPS IN INTERSTATE SYSTEM, 1979

Reason for Opposition	Number of Gaps	Length in Miles	Estimated Cost (1979)	Average Cost per Mile
No Opposition	119	1,150	$ 5,900,000,000	$ 5,000,000
Environmental Impact (Non-park)	28	313	$ 3,100,000,000	$ 9,900,000
Park Land Impact	10	77	$ 1,200,000,000	$15,000,000
Historic/ Archeological	14	166	$ 2,200,000,000	$13,000,000
Community Impact	39	270	$ 6,400,000,000	$24,000,000
Dollar Cost	6	19	$ 270,000,000	$14,000,000
TOTAL	**216**	**1,995**	**$19,070,000,000**	**$80,900,000**

Of the remaining sections the most controversial are in large cities and in the wilder and more beautiful areas of the country. The story of the West Side Highway, "Westway," along the Hudson River edge of Manhattan, and of the highways through Glenwood Canyon, Colorado and Franconia Notch, New Hampshire summarizes the effect of Federal legislation on American highway planning and construction in the 1970s.

Westway was originally conceived (although never formally proposed) as an eight lane, elevated, limited access freeway with balancing lanes, breakdown lanes and with West Street below acting as a continuous frontage road. This is, operationally, what came to be in the 1960s the standard, maximum capacity high performance urban extension of the interstate system. It is a design in which the trade-offs are between capacity on one hand and operating efficiency on the other. After ten years of work by a variety of consultants representing a variety of different interests, two alternative designs have emerged. Early in the debate the northern extension through Riverside Park was abandoned. Westway would be 4.2 miles long, from the Lincoln Tunnel at 42nd Street south to Battery Park at the tip of Manhattan Island. The two alternatives are quite different in scale, function and cost:

- The alternative proposed by the New York State Department of Transportation to the FHWA is a six-lane road, with inside lanes reserved for high occupancy vehicles during peak hour. Two miles would be in tunnels in landfill under the Hudson River. (The piers which once berthed the great North Atlantic passenger liners have been abandoned.) One-hundred-thirty-nine acres of new land would be created for commercial and residential development; 93 more acres would be created for parkland along the river. The estimated cost (1981) would be $1,400,000,000; the Federal share would be $1.4 billion. Part of the cost would be recovered by sale of land to private developers. West Street would remain a surface street providing access to the river front.

- A boulevard has been proposed, by opponents of Westway, as an alternative. Six lanes would be built on existing land outboard from West Street. The head houses of the piers would be demolished, but the fingers would remain. The estimated cost of the boulevard alone would be $125,000,000; parkland and some elevated and depressed sections of the boulevard could raise the cost to half a billion dollars. The city would claim the rest of the Federally-allocated funds for transit within New York City.

Construction of Westway as proposed to the FHWA was approved by the Secretary of Transportation in January, 1977. Westway is supported by Governor Carey, by both of the New York Senators, other elected officials, by the business community and the labor unions. Supporters cite the economic benefits to New York City as well as the transportation benefits. Opponents include several Federal environmental agencies and community, environmental, and transit groups in New York City. Mayor Koch reluctantly supported Westway for a while, but he has recently recommended the boulevard alternative coupled with mass transit investments.

Glenwood Canyon is the entrance to the heart of the American ski country, and it is the main route from Denver to the West Coast. In the 1930s the president of the Rio Grande Railroad, while riding through Glenwood Canyon and craning his neck out of the window to better see the Canyon said: "Let there be vista domes!" That is how the glass-topped trains came to pass; a granite monument at Grizzly Creek commemorates that event. The canyon is spectacularly beautiful; it is also spectacularly narrow.

In 1967 the Colorado Division of Highways (CDOH) began construction of Interstate 70 through Glenwood Canyon. Construction was stopped almost immediately by a coalition of local and national environmental groups. As a consequence of the 1973 and 1976 Highway Acts, interstate standards were relaxed in Glenwood Canyon and Franconia Notch, and representatives of the environmental opposition became active both in the selection of the highway designers and in reviewing their work. In 1976 the CDOH retained a design firm to advise it on the Glenwood Canyon work. In 1977 two other groups were selected to design the road through the two halves of the Canyon. The Citizens Advisory Committee for Glenwood Canyon (CAC) was decisive in that selection; about a dozen design groups were interviewed but the CAC would accept only those two groups that were finally selected.

As the designs evolved they were reviewed more or less continuously both by the CDOH and by the representative of the CAC on the Technical

Review Group and, once a month, by all seven members of the CAC and representatives of all of the public agencies with a stake in the Canyon. In the spring of 1978 a Design Public Hearing was held in which six of the seven CAC members supported enthusiastically the recommended design.[5] During final engineering the road is being refined following the same procedures that lead to the successful public hearing; construction of the western section has begun.

The road will cost almost a quarter of a billion dollars (1978) for twelve miles of highway, an average of $20,000,000 per mile. While this is marginally more expensive than the current typically difficult interstate gap section, if the dollar cost were increased the design probably would not be supported by the Federal Highway Administration. If the dollar costs were reduced, the environmental costs would certainly rise and the design would no longer be supported by the environmentalists. The design of I-70 through Glenwood Canyon has been a pricing process in the strict economist's definition of that phrase.

The problems in Franconia Notch are both similar to and different from the problems in Glenwood Canyon, and the outcome of the negotiations between the highway building agencies and the environmentalists has been different. Here, a legally binding "Agreement" has been reached between the New Hampshire Department of Public Works and the White Mountain Environmental Committee. (The WMEC is an umbrella committee representing all of the environmental groups that fought against construction of the road.) Franconia Notch is not a major, transcontinental route; peak traffic volumes occur in the fall when travelers come to see the foliage in the Notch itself. The debate about the road is, in a sense, an argument between two groups with different environmental interests.

The Agreement established the road as a two-lane road, one lane in each direction, through the most environmentally sensitive part of the Notch; as a result the new road can be slipped into the existing swath through the forest. (Minimum interstate standards call for two travel lanes in both directions.) Approximately $5,000,000 was allocated to the rehabilitation of Franconia Notch State Park. Earlier environmental damage to the Park, which had been substantial, had been mostly along the edges of the old road. In Glenwood Canyon, design of the road required trade-offs in which each interest group had losses which were balanced by gains to their interests. While final design of the Franconia road has not started, preliminary work pretty much assures that everyone will be better off after the road is built than before, even those interested in lower costs will profit from the change in standards. Even the seasonal tourists may gain; travel will be congested, but they will be gazing at a nicer Notch than they would have if an interstate cross section were inserted into the foliage.

Regarding the work of the two major design teams, the most controversial eight miles of the Chicago Crosstown Expressway were withdrawn from the interstate system in 1975. The remaining fourteen miles with an estimated cost of $1,200,000,000 are scheduled to be withdrawn. The Federal share of that money will be used for transit and local street traffic improvements in Chicago and Cook County.

Part of the highway designed by the Baltimore Design Team is under construction. Part of the rest has been shifted away from the center city to a tunnel under the outer harbor; two sections are held up by court injunctions, one because of its effect on a park and one because of its impact on an historic district.

In Washington, D.C. three miles of the interstate system have been withdrawn. The $375,000,000 saved has been applied to the construction of the Metrorail subway system. One mile, with an estimated cost of $100,000,000 has been reduced to parkway standards; design will begin this year. Ten miles of I-85, a circumferential highway around Richmond, Virginia, has been held up because of its economic impact on the older city center; three miles of I-235 in Oklahoma City has been held up because it affects a low income, black neighborhood; 23 miles of I-90 in Montana must be redesigned to preserve Indian relics; five miles of I-15 in suburban San Diego must be re-routed to save the few remaining specimens of a unique local plant.

The recognition that surface transportation systems affect the environment is part of the highway building process in America.

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CONFLICTS BETWEEN TRANSPORTATION AND ENVIRONMENTAL INTERESTS

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Abstract

Almost all policy decisions in the area of transportation involve conflicts with environmental interests. These conflicts arise from the fact that the welfare of large sections of the population is determined not only by the quality of the environment but also by the high degree of mobility that is desired. The result is continuous tension between the mobility needs of persons and goods on the one hand and, on the other hand, the need for space, quietness, and clean air. The interests of transportation and the environment should be weighed one against the other to determine the relative priorities. This procedure is of considerable importance and deserves further investigation.

To accomplish this, three case studies have been prepared of conflicts relating to quite different studies. All three cases occurred recently in the Netherlands. These studies involve railway noise, transportation, and energy versus the environment, road construction, and landscape protection.

Outlined are the backgrounds, selection procedures, results, and conclusions. The chosen cases all relate to quite different aspects of transport policy, but of all three, the common denominator proves to be "efficiency." Furthermore, the role of public opinion, the changing attitude towards public transportation and the problems arising from the analyses of environmental impact are made apparent. Finally, the need for "open-mindedness" with respect to the mutual problems of transport and of the environment is emphasized as an important element in the search for a solution to those conflicts.

Introduction

Almost all policy decisions in the area of transportation involve conflicts with environmental interests. In principle, these conflicts arise from the fact that the welfare of large sections of the population in the industrialized world is determined not only by the quality of the environment but also by the high degree of mobility that is desired.

With negotiations between transportation and environmental specialists, the emphasis is on finding compromises which do as little damage as possible to the vital functions of transport and which, whenever possible, guarantee optimal protection of the environment. In a period of recession, however, this selection procedure tends to be pushed into the background, as satisfying the demand for transport economic arguments tends to take precedence over environmental considerations.

Several of the instruments used in environmental policies can be applied to the transport sector, the ones which come to mind here are:

- taxation: environmental levies ("polluter pays" principle);
- standardization: emission standards (air, noise)--maximum permissible noise load;
- planning: routing of infrastructure; and
- construction: technical layout of the infrastructure.

Abatement at the source (quiet, clean vehicles) is important. Besides the above, many policy measures which are introduced from the transport point of view have an effect on the environment. The Environmental Impact Statement is one way of bringing these effects into the open and including them explicitly in the selection procedure.

In general, it can be stated that the various effects will be mutually interactive: environmental measures affect traffic, and transport policy will have certain consequences for the environment. In view of the fact that in formulating policies an integral approach to these mutual affects is either not possible at all or is impeded by conflicting interests, it would be interesting to investigate how in practice the selection and decision procedures turn out, especially in the case of conflicting interests. To this end, a number of actual cases which occurred in the Netherlands in the last few years have been analyzed.

In this paper, three case studies are presented which are intended to provide as wide a range of conflicts and solutions as possible. The chosen subjects all relate to various environmental measures and different aspects of transport policy:

1. A study concerning railway noise interim policy as it relates to rail transport which is subject to noise load standards;

2. The Supplementary Diesel Tax as it relates to automobiles with diesel engines; on environmental considerations a levy has been maintained which would otherwise have been phased out;

3. Amelisweerd, a study describing the attempts to solve the environmental and ecological problems resulting from the construction of a highway by way of physical planning and engineering measures.

In the case studies, besides giving the points of reference and the conflicts, an attempt is made to give an insight into the selection procedure which led to the final result.

Interim Policy On Railway Noise

In the early days of the railways, riding on a train was considered harmful to one's health because of the "devilish speed" of about 30 km/h and was therefore discouraged. Nowadays, we take a different view of this danger. However, railway traffic does cause some undesirable side effects, the most important of these effects being noise nuisance. For the Netherlands, a small but very densely populated country, the intrusion of railway noise as compared to other noise sources is shown clearly in Figure 1.

FIGURE 1

PERCENTAGE OF THE NETHERLANDS POPULATION HEARING OR AFFECTED BY NOISE SOURCES

	Percentage of the Population, Perception of the Source		
Source	Hear	Affected	Seriously Affected
Traffic	92	48	20
Domestic Noise	86	20	15
Aircraft	62	28	11
Industry	17	8	3
Rail Traffic	17	4	1
Other Sources	26	6	1

This situation gave rise to the formulation of an active railway-noise abatement policy in the mid-seventies. Although the Noise Abatement Act was already in preparation at the time, it was decided to introduce an interim-policy prior to the Act because of the lack of results of scientific research into the problems of railway noise. Later, after the necessary changes, the subject could be included in the aforementioned law. First in the list of priorities was the prevention of new bottlenecks by the construction of new railway infrastructure or new dwellings.

The attention was therefore focused on the so-called "new situations": new railways/new houses, new railways/existing houses, existing railways/new houses.

Although the need for such a policy and the priorities were agreed upon by both parties, it took the Ministry of Transport and Public Works and the Ministry of Health and Environmental Protection a couple of years to sort things out and publish a circular on railway noise containing recommendations for maximum permissible noise loads, criteria, and the calculation method. The discussions between the two Ministries showed the following starting points.

Environment

The same maximum permissible noise load as mentioned in the Noise Abatement Act concerning traffic noise should be imposed:

Day-L_{eq} = 55 dB(A), Evening-L_{eq} = 50 dB(A), Night-L_{eq} = 45 dB(A).

In addition to the standards for traffic noise, the sound level during the passage of a train should be mentioned: L_{max} = 70 dB(A).

Transport

The noise load limits applied to railroads should be higher than traffic noise load limits. Proposed standards:

(L_{eq}): Day = 70 dB(A), Evening = 65 dB(A), Night = 60 dB(A). No L max should be applied.

The above is based on the consideration that because of its nature and occurrence, railway noise will cause less nuisance than traffic noise with a comparable sound level. The application of noise standards should not cause zoning to such an extent that the accessibility of public transport is affected negatively.

Comparison of Railroad and Traffic Noise

In support of the difference in character of railroad and traffic noise, two major elements can be distinguished: acoustic characteristics and psychological and physiological characteristics.

Acoustic Characteristic

As well as the composing frequencies, the development in time of the sound levels differ greatly. Traffic noise to a significant degree consists of low frequencies. However, the application of the "A-weighted sound level" [dB(A)] greatly reduces the influence of these low frequencies. The insulation of the facades of houses is more effective in the case of railway noise due to the higher frequencies in the railway noise spectrum. Both phenomena give rise to a more favourable assessment of railway noise.

Psychological and Physiological Characteristics

Traffic noise consists of a great number of different sound components and presents often high and unpredictable peaks. Railway noise, however, shows more resemblance with wide-band noise (pink noise). The regularity with which trains pass and the predictability of traffic (timetable) are typical features of railways. These factors constitute an advantage for railway noise compared with traffic noise.

The Conflict: Noise Abatement and Accessibility

To prevent excessive noise levels being caused by railroad traffic, the following measures may be considered:

- measures at the source (silent vehicles),
- acoustic barriers or screens along the track,
- zoning (keeping distance between source and receiver), and
- sound-insulation of buildings.

The Noise Abatement Act prescribes under normal conditions the instrument of zoning for new situations. It would seem to be the most suitable instrument in this case because it offers protection from noise nuisance outdoors and because no special structures or constructions are necessary (barriers, screens, insulation).

The width of a noise zone depends on the intensity of the noise source and the permitted sound level at the receiver. The intensity of the source is mainly determined by the velocity of trains, their length, and the number of passing trains in a unit of time. The last two factors are expressed as the number of bogies per hour. Given a defined source, a lower permissible noise load will result in a wider noise zone.

From the point of view of public transport, a limited distance between infrastructure (station) and consumer is of vital importance in order to reach the greatest number of potential travelers. The so-called "circle-theory" shows an exponential decrease of travelers in the case of increasing distance between dwellings and public transport.

It also appeared that an open area between the station and buildings creates a kind of barrier which can reduce the number of potential travelers (Presikhaaf effect). To guarantee the accessibility of public transport, the limits of the noise load standard should be extended by 5 dB(A).

The conflict is clear: from an environmental point of view, wide noise zones should be created, but from the point of view of transport, there is no need for either zones or other noise-reducing facilities such as barriers, insulation, etc.

Negotiations

On the part of the Ministry of Environmental Protection, an advantage of 5 dB(A) for railroad noise above the limits for traffic noise was accepted. The importance of public transport for the environment being clear, the special "station-situation" was introduced, making possible smaller noise-zones.

The Ministry of Transport accepted 5 dB(A) restriction of the proposed standards which in theory could result in a maximum loss of 7% of the potential number of travelers.

Results

FIGURE 2
SOUND LEVEL L_{eq} IN dB(A)

Normal Situations			Station Situations		
Day	Evening	Night	Day	Evening	Night
60	55	50	65	60	55
24 hours: 60			24 hours: 65		

- Station situations: an area with a radius of 1500 meters from the station entrance. These standards could also be applied to the sites of future stations.

- The lower limit for the distance between houses and railroad is 25 meters, with the exception of railroads with a frequency of one per hour and no use during the night.

- These standards apply to situations in which the planning, design or construction of railroad, houses or both, can within reason be changed in such a way that the standards can be applied without excessive alterations.

- Day: 07 - 19 hrs., Evening: 19 - 23 hrs., Night: 23 - 07 hrs.

- L_{eq} 24 hrs. is the highest of the following values:

  L_{eq} day, L_{eq} evening + 5 dB(A), L_{eq} night + 10 dB(A)

- The standards are applied to the noise load at the front of the dwelling.

Conclusions

As accessibility for potential passengers is of vital importance to public transport, the distance between dwelling or place of work and the transportation system should be as short as possible.

Wide noise zones are an effective means of avoiding excessive noise loads emanating from roads and railroads. However, keeping distance creates a barrier between potential passengers and the transport system in the form of longer walking distances. There is a clear conflict of interests here.

A high permissible noise load--which is detrimental from an environmental point of view--will have a less adverse effect on transport as it will result in small noise zones or, if noise zones are not applicable, in minor acoustic measures aimed at increasing the sound transmission losses of facades, these measures being relatively cheap. The standard applied has a direct impact on the accessiblity of the transportation system as well as on the costs of any measures which might have to be taken.

In the "Interim Policy on Railway Noise" a compromise was presented. Experience with this policy has been obtained during the last two years. The comments given and questions raised during that period covered, among others, the following topics:

- Silent vehicles: The present standards are based on the expectation that the noise load caused by railroad traffic will be reduced by 5 dB(A) in the coming years. This gives rise to the following questions:
    a. Is it possible to decrease the noise emission of rail vehicles by 5 dB(A) in normal operation?
    b. Would reducing the noise emission of vehicles not be more expensive than the application of measures such as acoustic screens along the track which have the same effect on the noise load?
- Station situation: The local authorities are proving to be reluctant to apply the higher permissible noise load for the "station-situation." The fact that this special standard is based on the conditions necessary for the operation of public transport rather than on purely acoustic considerations makes it hard to accept. The question then raised is whether this exceptional situation can be maintained in a future policy.

When a definite policy in the framework of the Noise Abatement Act is to be drafted, then the above questions will have to be answered. In the meantime the Interim Policy on Railway Noise has proved to be a workable compromise between the interests of the environment and transportation.

Diesel Supplement: Transportation and Energy Versus the Environment

An example of a conflict between the interests of transportation and energy, on the one hand, and those of the environment, on the other, is the recent discussion in The Netherlands about the diesel supplement. In Holland the owner/user of a non-commercial diesel engine vehicle is subject to more taxes than the owner/user of a petrol-driven car which is equivalent in other respects. The differences are shown in Figure 3.

FIGURE 3
DIFFERENCES IN TAXATION OF DIESEL-ENGINE AND PETROL-DRIVEN VEHICLES

Taxes	Petrol	Diesel
Fuel Price	1.56	1.04
Vat	0.24	0.16
Excise duty	0.48	0.18
Air pollution levy	0.06	0.01
Various taxes	0.02	0.02
Annual Ownership Tax (non-commercial cars)		
Weight	Amount *	
651-750 kg	293	436
751-850 kg	356	526
851-950 kg	424	608
951-1050 kg	516	721
1051-1150 kg	612	837
1151-1250 kg	705	948

*All amounts in Dutch guilders; 1DFl = ± 0.45 U.S. Dollars (price level: January 1981).

As Figure 3 indicates, diesel fuel taxation is lower than petrol taxation; the differences stem from a lower excise duty, a lower air pollution levy, and as a result of the lower prices, a lower level of VAT (in cents). The owner of a non-commercial diesel car pays a higher level of road-fund taxes than the owner of a petrol-car--the so-called diesel supplement.

The above-mentioned system of tax measures has for the greater part a historical origin and is difficult to defend under the present circumstances. For instance, the diesel supplement was imposed in 1939 when, for practical reasons, only petrol excise duty was possible. Later, when the introduction of a diesel excise duty became possible and in fact was put to use, the diesel supplement was maintained for practical reasons. The differences in air pollution levy are due to the estimated quantities of pollutants which are produced by the burning of petrol c.q. diesel; the yield of this levy is used for the abatement of air pollution, so it is reasonable to make it proportional to the pollution that is being caused. When the levy was established in 1972 there was some awareness of the non-comparability of the total air pollution originating from the use of petrol and that originating from the use of diesel, but "one should make a start with these types of levies," as was pointed out in the Explanatory Note to the bill in question. The combination of a lower fuel price, a higher annual road fund tax, and the higher prices of diesel cars makes the ownership and use of a diesel can attractive only if a certain mileage per year is exceeded.

A few years ago, energy conservation strategies were discussed in the Council of Ministers. One possibility for energy conservation in the rapidly increasing transportation sector, which moreover is strongly dependent on oil derivatives, could be a relative growth in the use of diesel cars. Their low fuel consumption, compared with that of equivalent petrol cars, and the fact that the production of diesel oil requires less energy than that of petrol could result in energy savings of up to 20% per car. Discontinuation of the diesel supplement would stimulate the ownership of diesel cars and thus lead to an estimated energy saving of about 1% of the total energy consumption of the transportation sector. In other words, the increasing demand for mobility could be satisfied in a more energy-efficient way by making ownership of diesel cars more attractive. The decrease in tax yield could be compensated by an increase in the gasoline excise duty of about 0.5 cents.

Although discontinuation of the diesel supplement seemed to be acceptable at first, objections from the Ministry of Health and Environmental Protection were lodged at the last moment, leading to the cancellation of the plan. The objections concerned a number of air polluting properties of diesel fuel which might be more detrimental than those of gasoline. Although the use of diesel fuel causes a lower emission of carbon monoxide, nitric oxide and hydrocarbons, and no lead emission at all, the emission of sulphur dioxide, odors, and particles is considerably higher than that of petrol. In fact, the emission of particles, which is said to be forty to ninety times higher than that of petrol, has effects which are yet not very well understood, which makes it very difficult to compare the environmental effects of diesel with those of petrol. However, the Minister of Public Health and Environmental Protection was not willing to grant diesel fuel the benefit of the doubt and agree to a bill providing for the discontinuation of the diesel supplement. (It is interesting to note that up to the present the air pollution levy mentioned earlier has been six times as high for petrol fuel as for diesel fuel, thus stating implicitly that diesel is very much "cleaner" than petrol.)

Conclusions

Diesel fuel should not receive the benefit of the doubt. Should the use of this fuel possibly have more harmful effects on man and his environment than the use of petrol, then a government should not accommodate--indirectly, by a tax measure--the increasing use of diesel cars, even if both user (lower annual costs) and government (energy conservation) derive benefit from it.

Maintaining the diesel supplement was the conclusion of the Council of Ministers; the interests of transportation and energy conservation gave way to the interest of a clean environment.

The problem encountered in this case was the limited possibility for a proper comparison between the benefits and the negative effects of the use of different fuels. This could be characterized by the phrase, "no benefit of the doubt for diesel fuel," which underlines the need for a system that makes possible a more objective judgment. The comparison of the energy aspects of the use of different fuels does not cause problems; neither does the quantitative comparison of air pollutants. The missing link is the comparability of the effects of these various pollutants.

The aim should be towards a system of placing a value on these effects. In this way the various pollutants can be qualitatively compared and only that makes possible a realistic evaluation of all the important aspects which play a role in the comparison of the use of different fuels.

Amelisweerd: Road Construction and Landscape Protection

The central belt of the Netherlands is characterized by a large number of highways and intersections. There are, however, also areas in this region which are very valuable, both from an historical point of view, as well as from the point of view of the ecology and the landscape. It is obvious that the construction of new roads in such an area would soon lead to conflicts between the interests of traffic, and environmental protection.

A typical example is the construction of National Highway 27 designed for the regional traffic to the east of the city of Utrecht and for the national and international traffic between the southwest and the northeast areas of The Netherlands. This particular highway runs partially through and past the estate called Nieuw Amelisweerd.

This estate is situated along the Kromme Rijn. Nowadays, it is just a narrow stream, but in earlier days, until the tenth century, it was the main stream of the river Rhine. The area through which the river runs consists of meadows, woods, and orchards. The woods on the estate (total area about 65 hectares) were first planted in about 1700 and were redesigned in the present French style in about 1770. Just as the other estates in the area, Nieuw Amelisweerd has been opened to the public for recreational purposes.

Chronology of the Trajectory Choice

Since the first choice of trajectory for the highway was made in 1958 by the Minister of Transport, the plans have been changed several times. Originally, forecasts for the growth of the population and road-traffic were very high. New, lower population and road-traffic forecast in 1963 led to a review of the plans for expansion during which the highway was given a new route. In order to save the remains of the Roman settlement Fectio, the plan was again adapted in 1967.

In 1971, a pressure group was initiated which emphasized the ecological and historical value of the woodland area and its recreational function. The group wants the highway to be realigned in such a way that only the outermost parts of the woods are affected.

In 1971, the city council of Utrecht at last chose the final trajectory. The various trajectories are shown in Figure 4.

Construction

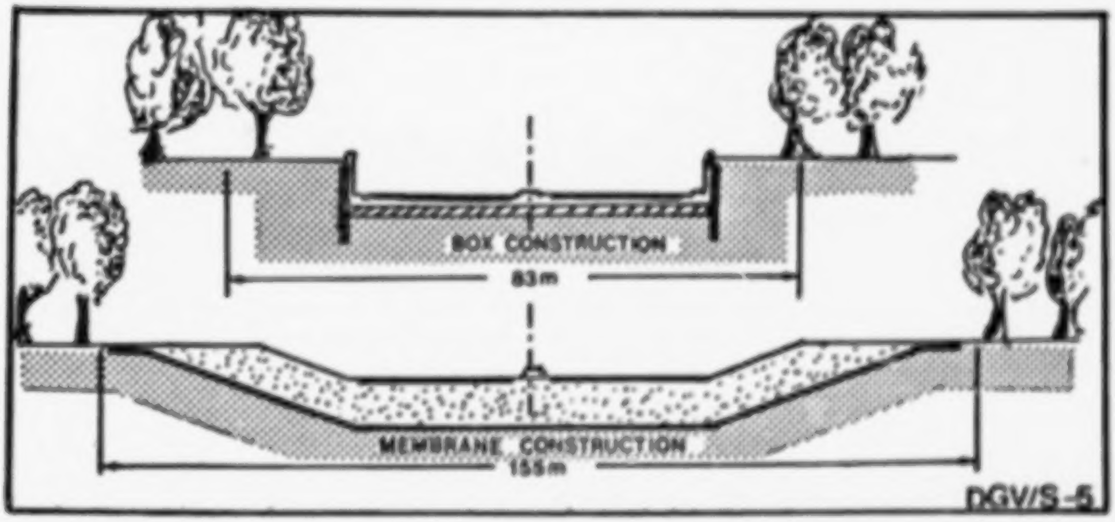
If one should think that this last trajectory, as shown in Figure 4, would leave the greater part of the woods in tact and that the problems were solved, one would be quite wrong. The 1971 trajectory offers the builders the possibility of laying the road below ground level. Studies proved that a membrane construction was possible which would have less effect on the landscape and would limit the noise hindrance. The costs of this kind of construction are approximately equal to the cost of constructing the road on a raised bed. A disadvantage is the wider construction area is necessary (maximum of 155 meters).

This great width met with opposition from the pressure groups which were of the opinion that too many trees would have to be felled and that the landscape would be affected to an unacceptable degree.

This eventually led to the development of the box construction (Figure 5), a type a tunnel with an open top. This technical concept is much more expensive than the alternative mentioned earlier. It has the same advantages requires less space (maximum width of 83 meters).

FIGURE 5

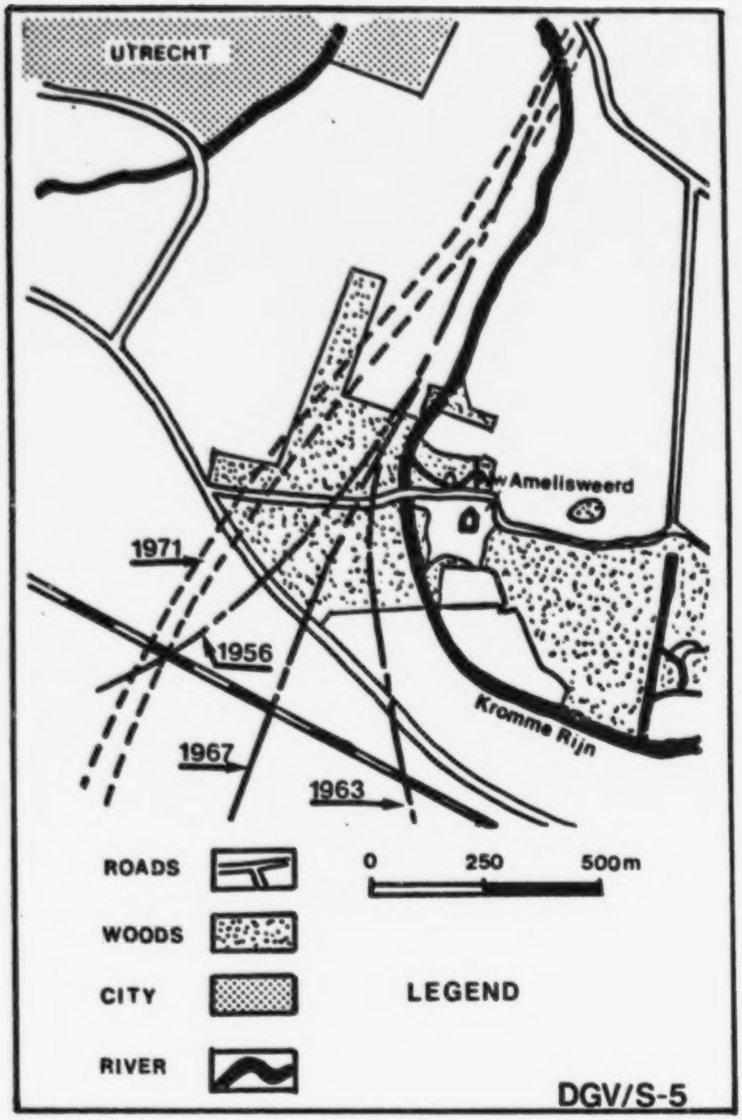
BOX AND MEMBRANE HIGHWAY
CONSTRUCTION



BEST DOCUMENT AVAILABLE

FIGURE 4

PROPOSED HIGHWAY TRAJECTORIES


UTRECHT
Amelisweerd
1971
1956
1967
1963
Kromme Rijn
ROADS
WOODS
CITY
RIVER
0
250
500m
LEGEND
DGV/S-5

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Administrative and Legal Conflicts

A crown-verdict in 1980 obliged the construction to be carried out according to the box construction method. Although in past years the City Council was a protagonist of the road, it is now delaying the construction by not allowing the excavation. The arguments are that traffic forecasts have been changed, and noise-abatement policies have been changed, which means that recreational areas now have to be protected. Public works, however, argues that although the forecasts have been changed--the amount of traffic expected in 1985 is now expected in 2000--the necessity of constructing the road still exists. Noise nuisance problems are partly solved by the construction methods employed, and extra measures will meet all requirements.

Conclusions

The initial problems which played a role in the construction of the highway were solved by measures in the field of town and country planning. The conflict only really became evident when, on the basis of the chosen trajectory, the construction was to be carried out. The two engineering options which have been developed are both characterized by the fact that the road is kept out of sight as far as possible and by the fact that construction and use of the road does not affect the level and quality of the groundwater. The space requirements eventually were decisive for the final selection, which would lead to an extra investment of DF 1.22 million (approximately 10 million U.S. dollars).

At present, however, changing social values have led to the necessity of the construction of the highway being doubted.

Overall Conclusions

Although the studies relate to quite different aspects of transport and environmental policies, some common elements can be recognized in the selection and decision processes. From the transport point of view, the aim is efficiency with respect to the use of energy (diesel supplement), the occupancy rate (public transportation railway noise), and costs (infrastructure at Amelisweerd). These are more or less traditional elements of transport policy.

The task of the environmentalists is often more complicated than that of those engaged in transport. The aim of the environmentalists to limit nuisance or damage to the environment is often frustrated by insufficient knowledge of the detrimental effects of pollutants. This may cause a drastic change in points of view. A typical example is mentioned in the case study of the diesel supplement and concerns the view on the detrimental effects of air-polluting properties of diesel fuel.

Public opinion plays an important role. The demands of people with respect to the quality of their environment poses ever increasing problems to traffic (see the Amelisweerd Study). Public transportation, however, increasingly finds favor with the public; the more positive attitude towards public increasingly finds favor with the public; the more positive attitude towards public transportation facilitated the negotiations for the Interim Policy on Railway Noise.

In the future the decisionmaking processes in transport and traffic policies will have to take environmental considerations into account to an increasing extent. The importance of an open mind for the arising mutual problems is emphasized. These conflicts should be avoided; close cooperation between both disciplines is essential. Recognition of the mutual interests is vital to the establishment of the aforementioned cooperation.

Acknowledgement

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THE IMPACTS OF URBAN TRANSPORTATION POLICY ACTIONS ON URBAN REVITALIZATION: SOME PRELIMINARY FINDINGS FROM THE NATO/CCMS STUDY

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Abstract

This paper will discuss the preliminary findings and conclusions from the NATO/CCMS Pilot Study on Urban Transportation and Urban Revitalization. The purpose of this study is to examine cases in which urban transportation actions are being used as measures to assist in the accomplishment of urban revitalization objectives.

The experiences of a total of eight cities in France, Germany, and the United States were examined. The transportation policy actions used by these cities included traffic management and restriction measures; improvement or expansion of existing conventional bus, tram, or rail systems; new highway construction; and improved pedestrian and bicycle facilities.

In general, the case studies show that a set of actions comprised of transportation and non-transportation measures was used to further urban revitalization objectives. Because urban revitalization is a process which evolves over time, in most of the case studies the final verdict on the success of the urban revitalization efforts is still outstanding. However, available evidence from the cities indicates that there have been changes in economic activity, urban structure, mobility patterns, and community perceptions influenced, in part, by the transportation-related urban revitalization measures.

Introduction

In the past several years there has been increasing recognition of transportation as a potentially useful tool in urban revitalization efforts. The NATO/CCMS (Committee on Challenges of a Modern Society) Pilot Study on Urban Transportation and Urban Revitalization looked at a number of European and American cities which have used or are using transportation actions to assist in the attainment of their urban revitalization objectives. This paper synthesizes the experiences of these case study cities.

Background of CCMS Study

Many governments, deeply concerned with the problems facing cities today, are developing remedies in which transportation actions play a major role. This is attributable to the potential ability of urban transportation actions to influence the location of jobs, dwellings, and patterns of movement related to economic, social, cultural, and recreational activities. The CCMS study arose out of a belief that an exchange of information on the experiences of cities using transportation actions as a tool for urban revitalization would be valuable. It was believed that, while national interests and viewpoints on urban problems may vary among the participating countries, there would be important insights to be gained through a comparison and cooperative analysis of the experiences of different countries.

The Concept of Urban Revitalization

At the outset of this study, it was recognized that the phrase "urban revitalization" has different meanings among countries and even among cities within the same country. The definition of "urban revitalization" depends on the existing conditions in a city and the values and priorities of its inhabitants. Thus, the results desired from urban revitalization efforts may vary widely. In some cities, the primary objective of urban revitalization may be to stimulate the urban economy in order to provide increased employment and/or increased revenues for the city government. Other cities may have the primary objective of improving environmental conditions in their revitalization efforts. The participants of the study agreed that it would not be fruitful to attempt to choose from among these diverse objectives in an international study. Therefore, for purposes of the study, "urban revitalization" is defined as any attempt to remedy identified economic, social, or environmental conditions in a city that is actually suffering from one or more of these problems.

Study Approach

The basic approach used was the case study method, with maximum reliance on findings from existing studies. The study participants believed that by examining the experiences of cities using different transportation actions there would be a high probability of obtaining some useful insights on the effect of these actions. In the case studies, identified problems which had been acted on were examined in their own setting. The merits of various types of urban transportation actions as tools for realizing the achievement of revitalization goals were then assessed in terms of their impact on urban structure, economic activity, environmental conditions, mobility patterns, and community perceptions. Because transportation is only one component of a set of complex factors affecting the outcome of urban revitalization efforts, the difficulty of drawing any direct causal links between transportation measures and impact on urban revitalization was recognized and acknowledged by the study participants. Therefore, the aim of the case study assessments was to fully consider the totality and complexity of the myriad forces at work in an urban environment.

Eight cities were selected for case studies. There was a set of larger cities (population over 400,000) and a set of smaller cities (population below 100,000).

The following cities participated:

- France - Aix-en-Provence
  Lyon
- Germany - Dusseldorf
  Freiburg
- U.S.A. - Burlington, Vermont
  Lowell, Massachusetts
  Minneapolis, Minnesota
  San Francisco, California

A wide array of transportation measures was implemented by the case study cities. The measures ranged from relatively low cost transportation management actions, such as restrictions on the use of private vehicles, to high capital cost projects, such as the construction of new roads and new rail transit systems. The urban transportation measures utilized included:

- Traffic management measures;
- Traffic restriction measures;
- Parking facilities;
- Improvement or expansion of existing conventional bus, tram, or rail systems;
- Construction of new rail transit systems;
- Construction of new highways;
- Pedestrian facilities;
- Bicycle facilities.

Summary of Findings From Case Studies

Objectives of Urban Revitalization

The case studies revealed two major concerns among cities undertaking urban revitalization efforts. In cities with economically declining downtown areas, the primary revitalization concern was with the stimulation of employment, commercial activity, and residential development in the central areas of the city. The degree of decline in the central areas varied widely among the cities, with some cities trying to prevent the outward movement of jobs and retail businesses before it could begin, while other cities were already experiencing the consequences of such an outward movement. This view of urban revitalization prevailed among the American cities, both large and small.

In cities with economically strong downtown areas which were experiencing traffic congestion and the resulting adverse impacts on air quality and noise levels, the primary concern in urban revitalization was to improve the quality of the environment for the urban residents. This concern appeared to be more prevalent among the European cities. However, it is important to note that the two urban revitalization concerns are not mutually exclusive and that cities tend to have a mixture of the two. Often, it is traffic congestion in the central city areas that contributes to the initial outward movement of retail businesses and employment to urban fringe areas.

Transportation Actions for Urban Revitalization

Regardless of the causes prompting city authorities to undertake revitalization efforts, there appeared to be general agreement on those transport policies which contribute to urban revitalization objectives. Such policies include improving access to and within the central area, but at the same time, relieving the adverse impacts of heavy auto use and enhancing the pedestrian environment. The specific actions utilized to implement these policies varied according to the particular needs and conditions of the cities. For example, the larger cities such as Dusseldorf, Lyon, and San Francisco tended, where feasible, to rely on rail rapid transit systems as well as highways for improving access to and within downtown areas.

Smaller cities, interested in economic growth in their central areas, relied primarily on highways to improve access to these areas. For example, in Lowell and Burlington, access roads connecting the downtown area with a major artery road were important transport elements of an overall revitalization plan. Improved highway access to the downtown area was often accompanied by the provision of additional parking facilities to accommodate increased traffic entering the downtown.

Improving access and environmental conditions within urban areas often involved the use of measures aimed at the management of traffic, restriction of private vehicle use, and the improvement of transit and pedestrian facilities. In Dusseldorf, traffic was diverted from the heavily populated inner city areas, and restrictions on single occupant automobiles were implemented in order to mitigate the air and noise pollution impacts of traffic congestion on urban residents.

Improved transit and pedestrian facilities often accompany the implementation of traffic restricted zones. These transit and pedestrian malls are usually constructed in commercial areas. Improvements in transit service are often implemented when a transit mall is constructed. For example, the transit loop in Burlington will enable the transit authority to modify its overall route system from one with many overlapping routes and numerous unrelated transfer points to a system where all buses will travel the loop at least once per hour (twice during peak hours) and there will be a common transfer point.

A primary purpose of pedestrian malls is to eliminate the air and noise pollution caused by vehicular congestion in order to create more pleasant surroundings for pedestrians and stimulate various activities contributing to the vitality of the street life. Pedestrian facilities were a major transportation element in the urban revitalization efforts undertaken in Aix-en-Provence, Burlington, Dusseldorf, and Minneapolis. The skyway system in Minneapolis is an example of a pedestrian system adapted to the specific conditions of a city. The skyway system, consisting of a series of enclosed aerial walkways connecting major commercial, employment, and retail buildings, provides a comfortable and convenient pedestrian circulation system, particularly during the long, cold winter months in Minneapolis.

Impacts

Given the complexity of the factors affecting the urban revitalization process, it is difficult to identify direct causal links between an individual policy or action and changes in an urban area. Often, it is unclear whether a specific transport action induced, accelerated, or merely accompanied a perceived change in the urban area. Further complicating the situation is the fact that the particular economic, social, and political context of a city determines, to a significant extent, the impacts of a particular action.

Because urban revitalization is a process which evolves over time, in most of the case studies the final verdict on the success of the urban revitalization efforts is still outstanding. In some cities the actions are still in the implementation stage, thus limiting further the conclusions that may be drawn. However, available evidence from the case studies indicates that there have been changes in economic activity, urban structure, mobility patterns, and community perceptions influenced, in part, by the transportation-related urban revitalization measures.

Changes in economic activity were observed to accompany the pedestrian facility improvements in Aix-en-Provence and Minneapolis. In Aix-en-Provence the Chamber of Commerce has estimated that retail sales figures have increased between 15% and 30% as a result of the new pedestrian mall. There is also evidence of increases in the selling price of businesses located along the mall. The quality and type of stores along the mall has also changed; there is a trend toward businesses specializing in personal goods, luxury foods, and speciality items and a progressive disappearance of small food establishments and businesses with a working-class clientele. Most existing businesses are less than five years old. In the past two or three years, a dozen new businesses have been started, dealing primarily in clothing and personal goods. The change in the type of shops is being accompanied by the renovation and expansion of available space in the commercial area. Rents and sales prices for residences along the pedestrian area have also been observed to increase. According to real estate specialists in Aix-en-Provence, apartments sell more quickly and for higher prices in the pedestrianized area. Old apartment buildings in the area are being divided up and renovated.

In addition to its impact on economic activity, the pedestrian area has also contributed to the promotion of cultural activities by providing a space for certain events such as the Acrobats and Street Entertainers Week and the Street Music Fair. At the same time, these new spaces are also being subject to free adaptation, creating a spontaneous and ongoing liveliness.

The skyway system in Minneapolis has opened another level of desirable space for retail and service establishments. This is reflected in the high occupancy rates for rental space connected to the skyway system and in the rents for this space which are equal to or higher than the rents charged for street level space.

In terms of impact on urban structure, the experience of the Market Street Corridor in San Francisco shows that a rapid rail transit system, in conjunction with favorable market conditions, supportive actions, and policies can have an impact on urban structure. In San Francisco, the share of downtown development occurring south of Market Street rose from essentially zero before the Bay Area Rapid Transit (BART) system opened (1960-62) to 80% during BART's initial years of operation (1974-77). The Market Street beautification project, modified zoning ordinances allowing more intensive development at BART stations, favorable land costs, and the overall attraction of the city for office activity all contributed to the growth south of Market Street. There was some speculation that the above factors might have been enough, without BART, to spur this growth. However, the BART Impact Program concluded after intensive analyses that BART probably did accelerate the shift of growth to the area south of Market Street.

While development occurred along the Market Street Corridor, expectations of transit-related revitalization and job creation were not realized along other portions of the BART corridor in San Francisco. This phenomenon may be attributed to a variety of factors including an absence of the factors found in the Market Street Corridor to facilitate development, neighborhood opposition to development believed to be inimical to the neighborhood character and anticipated negative environmental impacts.

Currently available data indicate that while the new subway in Lyon has had no real effect on an already tightly-woven urban structure, the system has brought about considerable changes in the travel patterns of the residents and in the amount of travel in the various sections of the city. The subway has reinforced the commercial centralization in the city. The subway has also played an important role in the revitalization of the commercial center in Lyon by relieving auto congestion into the center.

The experience of Lowell shows that, along with other inducements, the provision of adequate parking was instrumental in attracting a major department store to locate in the city. In addition, construction of an access road linking a firm with a major artery road influenced the decision by another major manufacturing firm dependent on trucking for distribution of its products to remain in Lowell.

Conclusions

In general, the case studies showed that a set of actions comprised of transportation and non-transportation measures was used to further urban revitalization objectives. These actions often resulted in changes in urban economic activities, mobility patterns, and the quality of the urban environment.

Several of the cities studied expressed concern about the unintended impacts resulting from urban revitalization. One concern involves the revitalization-devitalization conflict in an urban area. Urban revitalization efforts tend to be focused on specific areas of a city rather than an entire urban area. Therefore, revitalization may simply result in a shifting of economic activity within an urban area in the absence of overall economic growth in the urban area. To the extent that there is such a redistribution, one unplanned consequence of urban revitalization may be to intensify the competition for economic activity among the various parts of an urban area. This concern was highlighted among cities trying to halt the outflow of employment and retail activity to outlying urban fringe areas. The Lyon case study expressed a concern about the possibility that the centralization of commercial activity, caused in part by the new subway, would eventually have the effect of devitalizing peripheral areas.

Another concern involves the displacement of urban neighborhoods resulting from urban revitalization. Often, those displaced are the poor, elderly, and minorities who tend to be less politically capable of protecting their interests. For example, in Aix-en-Provence the neighborhoods affected by the pedestrian zone were inhabited primarily by the elderly, poor, and immigrant workers. The transformation of the residential and commercial area accompanying the creation of the pedestrian zone resulted not only in housing unsuited to the former residents, but the new prestigious character and image of the entire area was foreign to these people and tended to exclude them. Therefore, the former residents are slowly leaving the quarter. This social change and growing segregation are accompanied by a change in the characteristics of daily neighborhood life.

One negative environmental impact of the office construction along the Market Street Corridor is a reduction in the amount of sunshine, light, and the sense of openness which had prevailed, at least along the north side of the street. In addition, unpleasant wind movements are often experienced at the base of the new tall buildings.

To the degree that urban revitalization may shift the economic balance within an urban area or displace the poor from their neighborhoods, there is a need for more consideration of the impact of revitalization on the spatial distribution of activities and on the burdens borne by various population groups, in particular the poor, elderly, and minority groups. There is also a need for more careful scrutiny of the goals urban revitalization and their relationship to the larger economic, social, and environmental goals.

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THE INFLUENCE OF TRANSPORT ON URBAN PERFORMANCE

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Abstract

Consideration of the historical development of towns shows that their scale has been set by the prevailing travel speed, but the present ubiquity of the private automobile means that urban development is perhaps less sensitive to individual changes in the transport network than it has been in the past. The basic trade-off between the desire for personal space and good accessibility to a range of desired activities (a range which tends to grow with time as affluence, transport, and technological progress expand the possibilities) is understood qualitatively, but because prediction involves the summing of opposing tendencies, we need a much better quantitative understanding than we have at present.

This paper reviews briefly both empirical studies of the impact of new transport facilities and the type of modelling work which attempts to provide an understanding of the mechanisms involved by representing the two-way interaction between land-use patterns and the transport system. Studies of the effects of introducing urban rail systems and new freeways suggest that, in many cases, the transport improvements have indeed encouraged greater urban development, but this only happens when several favourable factors all coincide. Moreover, it seems that planning policies impose the most important constraint on how land use will be affected by transport, and these policies are often intimately connected with the design of the transport improvement. Several different types of models are described at varying levels of sophistication and aggregation. They have provided considerable food for thought, but their predictive and prescriptive abilities are largely untested and probably unreliable. The very long response time of urban development renders the proving of all these models problematic, but much could be learned from a systematic comparison of the behavior of different models run under similar conditions. At present there is widespread scepticism of the value of this work, but if progress is to be made in understanding the long-term effects of transport policies, there is no practicable alternative to attempting to assemble the available knowledge into some form of quantitative model.

Introduction: A Historic Perspective

The time taken to travel from one place to another has always acted as a constraint on the maximum size at which cities could function adequately. Before mechanised transport became available, the vast majority of travel within towns was on foot, and the maximum size of the most important cities stayed much the same over the centuries. Pushkarev and Zupan[1] have argued that, although the coming of mechanised public transport enabled cities to grow in size, it was only the private automobile which encouraged population densities in built-up areas to fall below levels which had remained fairly stable over the centuries. They illustrated this thesis using data from cities back to Roman times, and though these statistics are purely illustrative, since the sample of cities for which data are available is in no way representative, it is also interesting to reinterpret their data in terms of a mean city "diameter," calculated crudely from the populations and mean population densities within the city boundaries. The results are summarised in Table 1, which suggests that, while medieval cities were of much the same dimension as those in ancient Rome, major European cities with public transport networks were some ten times larger in diameter even before the coming of mass automobile ownership, and the automobile age itself has seen a further expansion by a factor of three or four (and by considerably more in some North American conurbations). The first half of the nineteenth century saw the growth of industries which employed workers on a much larger scale than previously, and which tended to congregate together to share the advantages of proximity to one another, to the sources of raw materials and energy, and to the shipping of their products and materials through the coastal or inland parts. The concentration of labour required by these industries and the need to keep travel distances within the bounds imposed by walking as the only generally available transport mode for their workers gave rise to excessively high population densities in the inner city areas: densities equivalent to 100,000 persons per square km were common in the largest industrial cities, a concentration which had serious implications for health and general wellbeing.

Although city transit services by horse bus (and horse tram) appeared early in the nineteenth century (Paris 1828, and London 1829), the networks were limited and the speeds little faster than walking. It was the coming of passenger services on the steam railways in mid-century which finally permitted the dispersion of the tightly-packed population in the inner areas of the largest cities. A further significant expansion occurred when the greater acceleration of electrically-powered vehicles was used in surface tramways (both New York and London in 1888) and underground railways (London 1891 and Paris 1900) with relatively closely-spaced stops, giving quick access and fairly rapid travel. This progression in urban development is clearly visible in the type of graph plotted by Bussiere.[2] This approximates the decline in population density outwards from the city centre by a negative exponential function, $D(r) = A\exp(-br)$, a relationship proposed by Bleicher[3] as long ago as 1892. Here, $D(r)$ is the mean population density at radius r; b measures the rate of decline with distance, and A is the extrapolated value of the density at the centre. In fact, most cities have population densities of much less than A at the centre as the population has moved outwards, leaving a "crater" in the residential distribution primarily occupied by commercial and industrial activity. Figure 1 shows how the values of A and b have changed over time in both London and Paris.[4] In both cases (and in all other cities of the Western world) both A and b have declined as the cities spread to cover a larger area at lower density. For London the census data exist from 1801, and it can be seen that the first half of the nineteenth century saw an increase in densities as the city grew, because the rural population migrated into the city faster than the city could expand outwards, since its size was constrained by the prevailing low travel speeds. Even so, the pressures for urbanisation gave rise to a city of diameter considerably larger than those typical of previous ages and where the distances involved were inconveniently large to cover on foot. The impact of steam railways (both surface and underground lines), which made it possible for the growing population to live further from their work, is seen from mid-century onwards as A falls, and the further acceleration due to the mushrooming of electric tramways and underground rail at the turn of the century is also clearly marked. The data from Paris begin later in time, but the impact of the new Metro System is seen to be very similar. Interestingly, when Putman[5] tried to represent the evolution of nineteenth-century Philadelphia using the locational model DRAM, he found a discontinuity in the calibration parameters around 1860 which he attributed to a combination of a boom in house building with the introduction of a horse-tram network which, in spite of its low speed, permitted a marked increase in travel distances.

Public transport still provides an incentive for people to concentrate along the corridors served by the transit network so that, although it certainly helped to remedy the worst excesses of the slum concentrations, overall population densities were not reduced appreciably below those prevailing before the age of machinery. The private automobile, by contrast, not only reinforced the tendency for people to live further from their work (or from other facilities), but its "go-anywhere" property also released people from the need to congregate within easy access of the transit routes. The low-density development it encouraged is not apparent in the graphs of Figure 1 (though the data exclude much of the development which has sprung up outside the Metropolitan areas proper in the last two or three decades), but it is common experience that mass automobile ownership has nurtured and given reality to that dream of a separate house and garden which seems especially prevalent in Anglo-Saxon countries, but which is also increasingly sought in other developed countries. Los Angeles is the archetype, of course, with a built-up area more than 100 km across (N-S), but many other cities show similar suburban development, if on a more modest scale. While there has been a shift of homes and facilities away from the city centres, there has also been a tendency for greater centralisation of some facilities into peripheral locations which are easy to access by automobile. The increased mobility has encouraged services and facilities which can benefit from economies of scale, but which previously operated on a small scale in catchment areas delineated by the inconvenience of travel, to congregate in larger, but more widely-spaced units. Thus, the corner store and local hospital have been replaced by the suburban hypermarket and the regional hospital. This confers the advantages of cheaper and more varied goods and better facilities on those who have a car available, but it puts those who do not at a severe disadvantage. This distinction is very pertinent in considering the "performance" of a city.

FIGURE 1

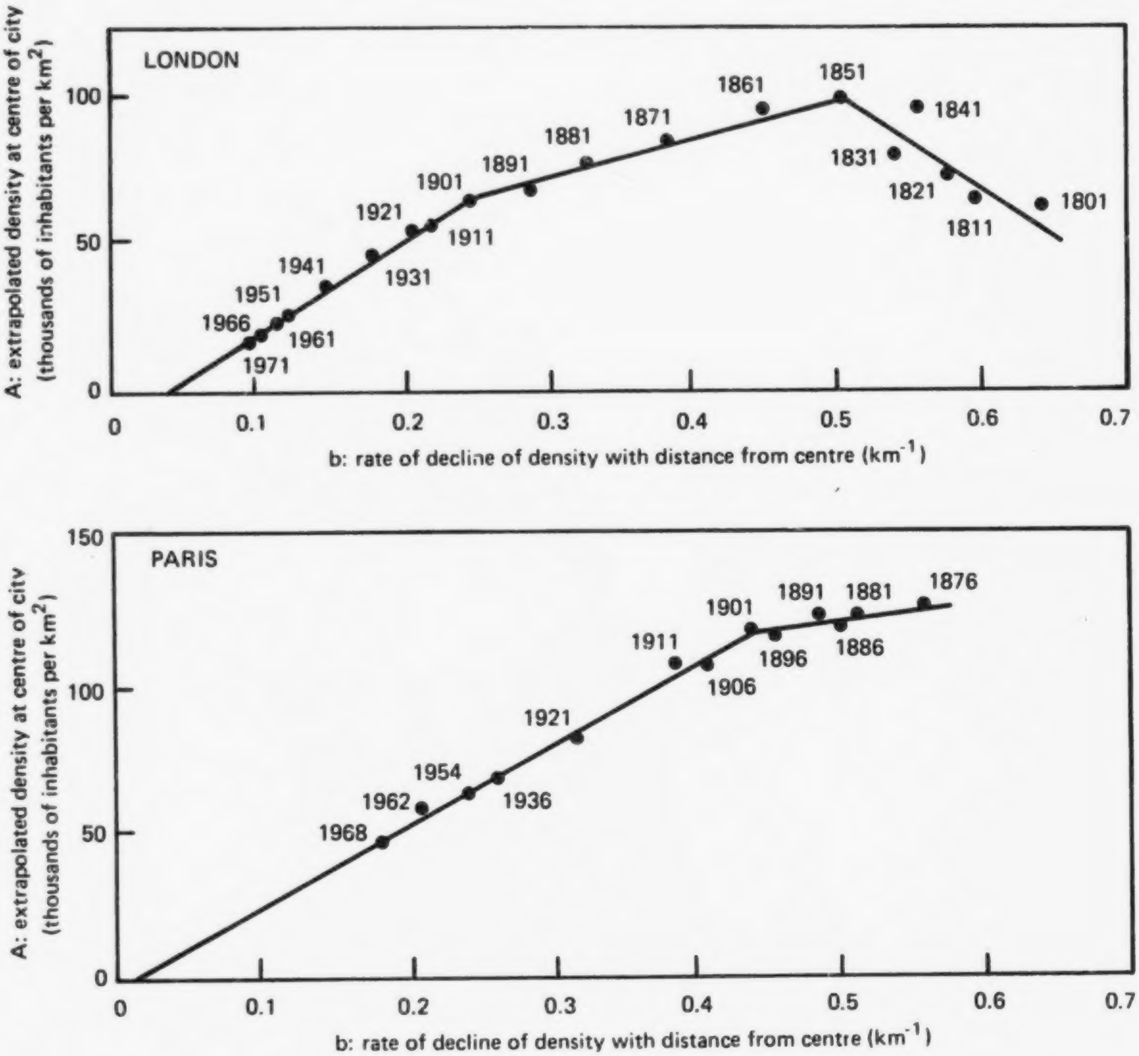

Fig. 1 Trends in population density in London and Paris (variation of the parameters in the negative exponential distribution of population density: Density=Aexp(-br). Source: reference 4)

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TABLE 1

CITY SIZE AND THE EVOLUTION OF TRANSPORT[1]

Cities	Population	Population density (inhabitants per km^2 of built-up land)	Approximate "diameter"+ (kms)
Ancient Rome*: pedestrians			
Rome (86 BC)	463,000	37,000	4.0
Pompeii (63 AD)	11,000	16,000	0.9
Dura-Europos (100 AD)	7,000	13,000	0.8
Medieval Europe: pedestrians Venice, Siena, Strasbourg, Paris, Cologne, Hamburg, Pisa, Prague, London, Florence, Nordlingen (14th and 15th centuries)	Mean: 39,000 Range 11 to 78 thousand	Mean: 14,000 Range 10 to 24 thousand	Mean: 1.8 Range 1.1 to 2.6
20th Century Europe: pedestrians and transit Prague, Vienna, Hamburg, Berlin, Munich, Leipzig, Cologne, Frankfurt, Essen, Dresden, Dortmund, Moscow (1938/52)	Mean: 1,470,000 Range 550 thousand to 4.8 million	Mean: 16,000 Range 7 to 34 thousand	Mean: 18 Range 12 to 33
20th Century: transit and automobile Paris, London, Chicago, Philadelphia, Los Angeles, New York, Dallas/Ft. Worth (1956/71)	Mean: 5,810,000 Range 1.8 to 8.2 million	Mean: 7,000 Range 1.5 to 17 thousand	Mean: 62 Range 31 to 145

+Diameter of circle containing population at mean gross population density (i.e., including land which is not built up).

*But the three Roman cities were totally dominated by Rome itself, which was uniquely large in its day, with a population of almost half a million at very high density in an area some 4km across: the two other cities were relatively small.

Empirical Studies Of Transport Changes

It was seen in Figure 1 that, at a very aggregate level, the introduction of public transport seemed to have had a very pronounced effect on city development. At a more detailed level, too, there is plenty of anecdotal evidence about the effects of the new rail services on land and property markets, and of the fortunes that were won and lost by speculation in potential transport corridors. Scientific studies of the land-use impacts of transport changes were not made until much later and, compared with what might have been expected on the basis of the history of the earlier period, the results have generally been disappointingly inconclusive.

The more comprehensive studies seem to have been associated with rail public transport rather than road-schemes and, understandably given the flurry of rapid transit building in North America in the past decade, most of the literature is American. Many of these studies have been able to show a correlation of both commercial development and higher density residential development with the location of rapid transit stations (examples can be found in Boston,[6] Montreal,[7] Philadelphia,[8] San Francisco,[9] and Toronto,[10] but the bibliography is quite extensive). However, it is often not clear to what extent some of this development would have happened anyway, or whether it appeared primarily because of other factors. Where development could be linked unambiguously with the presence of the rail line, there was evidence that some of it was simply a relocation of development which would otherwise have occurred in a somewhat different place. A comprehensive review of the available information about the impact of new transit systems (rapid transit, light rail/tram, and busway), mainly in North America but with a brief coverage of Europe also, has been produced by Knight and Trygg.[11] They come to much the same conclusion as was reached by Spengler[12] in his 1930 study of New York's transit. According to Spengler, though the introduction of rapid transit lines provides an important inducement to intensified development along the corridors serviced, this will only come about when the pressures for development already exist. In this way, transport changes can facilitate development and encourage it to occur in some places rather than others, but they do not of themselves cause urban development. Several favourable factors must come together to generate the growth.

For this reason, Knight and Trygg doubt that public transport schemes lead to any extra growth in the urban economy as a whole. The effect is to cause shifts in development within the city, rather than net increases in land values or economic activity. However, given the difficulty of attributing unambiguously even local growth to the nearness of the transit line, the assessment of regional impacts, where the effects are extremely diluted by other factors, is likely to be an all but impossible task. At a global level, a long-term improvement in the overall economy might only be expected to stem from an improvement in passenger transport in so far as it will save travel time and some of this time will be spent productively. As we shall see later, increased travel speed seems to be traded for longer travel distances so that there is no appreciable reduction in the total time spent travelling, though the improved accessibility might lead to a more efficient meshing of the right type of worker with the type of job. But in any case, in most situations, public transport schemes affect a relatively small proportion of the population and usually in a fairly small way, so that it does indeed seem plausible to suppose that they can have little effect in improving one city's position in competition with other cities. Nevertheless, if their effect on land use is only to cause a relocation of development, this in itself can be an important planning tool. It is also conceivable that the long-term impact will be greater than the present (inadequate) information suggests, though the argument involves a good deal of supposition: if transit systems do encourage more concentrated patterns of development, and if such patterns do offer greater economic efficiency and support urban forms and a way of life which ultimately proves more attractive (especially as transport fuels become more expensive) than the dispersed development which results from individuals optimising their immediate living conditions, the cumulative effect could be considerable. Of course, there is little evidence to suggest that this will be so, but the point is that, at the moment, we do not know enough to write off the effects as being unimportant.

In developed Western countries the major mechanised mode of travel is private automobile rather than transit, and most freight in urban areas also travels by road. It might be expected, therefore, that major road schemes would make a larger impact than transit schemes. However, mass car ownership has produced such a high level of accessibility and such an isotropic travel pattern that only the largest road schemes are likely to make much of an impression on overall activity patterns and on pressure for development in different areas (though it is obvious that individual developments must rely on construction of local road systems). As far as residential development is concerned the impact is also likely to differ from that of a rapid transit line in that, since access to the road is by automobile, there is not the same incentive to live very close to a new highway; indeed, there is some incentive to put some distance between the highway and home in order to avoid noise, fumes and visual intrusion (the same inconveniences may also be present with transit, of course, but the advantages of walking access can override these). Industry and warehousing, by contrast, can benefit from direct access to a major trunk route. There is insufficient space here to refer to many of the reported studies of the impacts of new freeways on land development, and no comprehensive review seems to be available. Khasnabis and Babcock's study[13] of several different cities in North Carolina where new freeway by-passes, beltlines or through-ways have attracted new commercial and residential development, and Parker's investigation[14] of the effect on residential development of a new freeway in Los Angeles, must serve as examples. The general conclusion culled from such studies is in line with that obtained from the transit studies: there are often significant increases in land values and in development close to the road access points, but this does not seem to happen in all cases, it is dependent on other factors, and it may well largely represent a transfer from areas further away.

On the whole, then, the effects of transport changes on land-use patterns are not so profound (at least in more recent times) as to be immediately visible and unarguable. That the impacts should often appear to be fairly modest is hardly surprising, since new transport schemes usually provide only a modest increase in overall travel speeds, and their effects are confused by a continually changing pattern of development due to a host of other factors. Nevertheless, it is worth noting that the uncertainty of measurement can be greater than the capital cost of the transport infrastructure. This is a point made by Wacher,[15] who investigated the changes in land values around the newly constructed Victoria underground rail line in London. He estimated that land values were 1% to 5% higher, according to area, than they otherwise would have been, though this rise must be seen against a background of land values rising at more than 10% per year generally, which rendered the exercise rather uncertain. The net increase in value ascribed to the introduction of the line was greater than the capital cost of the section of the line in the study area. Therefore, land-use effects could be an important component of the economic justification of such schemes.

A major conclusion of Knight and Trygg's study[11] and of an earlier review by Libicki,[16] of North American transit improvements, was that the impacts can be moulded greatly by the prevailing planning policies, and that these policies themselves can be strongly influenced by the transit schemes. Since both the scheme and the planning policies are often under the control of the same authority, it is generally the case that the policies are aimed at enhancing the impact of the transit scheme on development (by zoning for higher density development in the vicinity of the stations than elsewhere, as in Toronto), though counter-examples also occur. In a suburban area of the BART system, initial local opposition to construction of the line was appeased by guaranteeing that zoning would be restricted to low-density development, thereby squashing any opportunity for concentrating activities around the station.[17]

In Europe, where planning constraints tend to be stronger than in much of North America, the interconnection between transport planning and urban planning is even stronger, so that the transit scheme and the wider land-use framework have in many cases been designed cooperatively. This is perhaps most visually obvious in the new satellite towns such as Farsta or Kista surrounding Stockholm. Here, high-density residential development rises abruptly from more-or-less open countryside, clustered around a shopping centre which incorporates a station of the urban rail system, and an interchange with the local bus services. In this situation it is pointless to try to disentangle cause and effect in the relationship between land use and transport. But, however strong, planning controls can only be absolute in a negative sense. Development can be prevented, certainly, but planning permission of a particular type does not ensure that private developers will come along to build; construction of rapid transit lines in both Chicago and Cleveland seems to have had little effect on development because the areas penetrated, and the positioning of the rapid transit stations, were unattractive to developers.[11] Even if the public authority itself puts up the buildings, there is no guarantee that houses will be filled or offices let (unless the choice of alternatives is very limited indeed).

Thus, even with effective planning controls, the results may still be unexpected and not necessarily visible in terms of gross land use. In Munich, for example, although the new underground rail services and improved commuter rail network have enhanced the dominance of the CBD for both employment and retail activities as was intended (incidentally suppressing several local centres), it has also had the unexpected and unwanted effect of encouraging spatial segregation of the rich and poor, according to Kreibich.[18] The more affluent residents have taken advantage of easier commuting to move into the outer suburbs where house prices have risen, leaving low-income families concentrated in inner city areas which are not well-served by rail, and less well-served than formerly by a reduced network of bus services. Ironically, one spin-off of this out-migration of the more affluent group is an increase in car travel in the outer suburbs.

In attempting to summarise the empirical studies, it is very apparent that few useful generalizations can be made. The evidence shows that transport changes do affect land use and that the effect can be important. However, because the impact depends on so many local factors, it is hard to identify it even in retrospect, let alone in prediction. How then can all this information and experience be consolidated in a way which will lend credence to assessments of the likely outcome of different policy alternatives? The only hope for progress seems to lie in studying the reactions of people and institutions to changes in transport and changes in land use and to assemble this knowledge about the behavior and about all the interactions involved into a consistent and quantitative framework. In short, it is necessary to construct some sort of model against which to test and improve our understanding of observed behavior. In this way the transport component is separated from the confusing influences of other factors. The difficulty, of course, lies in getting the model right.

Urban Modelling

The complexity of a city might seem so great to most people as to deter anyone from attempting to represent it by some sort of mathematical model. Nevertheless, while it is quite true that the detailed development of any city depends on a multitude of different factors, most of which are completely outside the field of transport, the essence of modelling is to reduce the system to those mechanisms which are deemed to form the overall "shape" of the behavior being investigated, sweeping aside the mass of lesser detail into that warning which is routinely associated with predictions of this sort, "other things being equal." Herein lies one of the strengths of modelling. It can guide understanding through a confusion of differing behaviors to an identification of the underlying framework. It is also a great potential weakness, because the neglected detail may have, in aggregate, a larger influence on the behavior of the actual system than the supposed controlling framework. Thus, there is a fine balance to be achieved between putting in sufficient detail to account for the behavior of the system being modelled, but not so much that the model becomes impossible to calibrate and operate.

The Balance Between Accessibility and Space

The basic principle of how transport affects location decisions was stated as long ago as 1826 when Von Thunen[19] suggested that the rent paid for agricultural land plus the cost of transporting produce to the local market centre would be constant so that rents would decline with distance from the centre. Translated into urban terms, location depends on a trade-off between a desire for ample space for individuals to live in, as far as home location is concerned, or for trading, commerce or manufacturing, as far as job location is concerned, against cheapness of access (in terms of money, time, and effort) between home and work, and between home and the many other activities which take place away from home, and between the various commerical activities.

However, the present tradition of modelling has its roots in the late 1940s and 1950s with the realisation in the United States that mass car ownership was having a profound effect on travel patterns and that urban planning would have to change if it were to cope with the new mobility. Modelling of transport flows within a specified land-use pattern (trip generation, distribution and assignment in the familiar Land-Use/Transportation Study) became established in the 1950s. There was then a natural progression from interest in this sort of prediction to attempts to represent the changes in the landuse pattern itself, especially the impacts of the greatly improved accessibility conferred by increasing car ownership. Consequently, several models representing locational decisions and urban development were created in the 1960s.

There is insufficient space here to describe in any detail the many urban models which have appeared in the literature. Besides, several competent reviews already exist: for example, Batty's book[20] provides a detailed mathematical account of the development of urban modelling, while Putman's review[21] provides a more verbal description of North American work in particular. It seems more useful here to concentrate on those models which are in current use and on their applicability to policy evaluation, especially where there is a strong transport component. (Some of the more economically-oriented urban models include transport only in terms of a very crude and aggregated accessibility, which often depends only on crowfly distances.)

Several of these models owe their inspiration to the Pittsburgh model built by Lowry.[22] This took the location of "basic" industry (i.e., manufacturing and primary) as given, and from the amount of employment available both in basic industry and in the retail and service sectors, estimated the total population which could be supported. This population was located then in the various zones of the area modelled in proportion to the "population potential" of each zone. This "potential" was a function of the distance from the zone of residence to all other zones containing employment, weighted in proportion to the amount of employment available. Once the population had been allocated, retail and service employment was located according to the "market potential" of each zone, which depended upon the population in the surrounding area, its accessibility to the services in the zone, and on the basic employment in the zone. Naturally the whole process is iterative since the population and market potentials depend upon the location of population. In addition, limits were placed on the maximum residential density in any given zone, and "surplus" population had to be redistributed in a subsequent iteration.

Although Lowry's model was calibrated on Pittsburgh data with a fair degree of success, it was rapidly overtaken by more sophisticated models as, once the basic feasibility of this type of modelling had been demonstrated, ways of improving its obvious lack of refinement became apparent. Several urban models which might be loosely described as Lowry-derivatives are currently being used or developed, though their elaboration of the basic theme is such as to make them very different in appearance from the original Pittsburgh model. Models which fall into this category include Putman's Integrated Transportation and Land Use Package (ITLUP),[23] the several variants of Echenique's model (often referred to as the ARC model, since it was developed by Applied Research of Cambridge),[24] Mackett's model of Leeds,[25] the model of Toronto constructed by Hutchinson and Said,[26] and a model of the Amersfoort Region of the Netherlands currently under development by Floor and de Jong.[27] All of these models incorporate a more flexible version of Lowry's home and employment allocation mechanisms. First, the probability of locating in a given zone is not simply a function of the zone's accessibility to employment or population, but it is dependent also on a measure of the zone's "attractivity." At simplest the attractivity can be an empirical constant of the calibration, as in the still-developing Amersfoort model, but in the other models the attractivity is some function of the type and intensity of development in the zone. Secondly, the population and market "potentials" of the Lowry model have in all cases been replaced by "entropy-maximizing" gravity functions in the formulation suggested by Wilson.[28] This particular dependence of the probability of location on the costs of travel to all other potential destinations (in general, the costs include both money and time spent on travel) has a certain mathematical convenience: indeed, the ITLUP model initially incorporated the Projective Land-Use Model (PLUM) which Goldner[29] constructed as a direct development of the original Lowry model, but Putman found it necessary to recast the simple gravity models of PLUM into an entropy-maximising form in order to calibrate the model properly.[30]

The POLIS model[31] built in Frankfurt's Batelle Institute also assumes that the probability of location in a given zone depends on the zone's accessibility and an "attractivity" combining many different attributes of the zone's facilities, but it deals with the problem of locating buildings, employment, facilities and homes by means of a very detailed simulation. The allocation is hierarchical: public construction and transport programmes are implemented first, followed by private development which is located on the basis of attractivity and availability of land for development, and of the profitability of providing buildings of a particular type in a particular place. The model is interactive, so that "planning decisions" can be entered as the simulation proceeds. Wegener has used his experience of the POLIS model to construct a three-stage model of the Dortmund area,[32] in which an economic model of the entire Nordrhein-Westphalia region is used to predict overall employment and population changes in the city of Dortmund. A model similar to POLIS then simulates changes in development, employment and population in 12 zones into which the urban area is divided, and a third stage of the package then models construction in even finer detail in the 171 districts within Dortmund.

Two other models investigate urban development not in terms of how a city is likely to develop under alternative planning policies, but by identifying that pattern of development which will maximise the "welfare" of the community. The rationale here is that the situation produced by individuals trying to optimise their own situations is not necessarily the best arrangement for the community as a whole. This tenet, of course, provides the fundamental justification for all centralised planning and, indeed, several of the models which predict behavior and development under different policy options also provide a facility for "evaluation" which totals the various kinds of costs incurred in each case. However, the TOPAZ model[33] of the Commonwealth Scientific and Industrial Research Organization, Australia, and Lundqvist's TRANSLOC models of Stockholm[34] go further, by actually minimizing a compound cost function. In TOPAZ the sum of the total travel costs and the costs of locating new buildings in the different areas is minimised, and in some applications an empirical "willingness to pay" for the intrinsic attractiveness of some locations compared with others has been added into the total "cost." TOPAZ can also be used in a manner which maximises the welfare of the individuals, as opposed to the community. TRANSLOC minimises a combination of a travel cost, which includes not only the time and money costs of travel, but also "opportunity costs" which represent the disadvantage of having only a limited choice of destinations close at hand, plus the cost of having limited space to live in, which is taken as being proportional to the prevailing residential density. Naturally the notion of an "optimum" land-use pattern is to be treated with caution, since many other attributes of urban life are ignored in such narrowly-defined objective functions; this caution is made explicit in the case of TRANSLOC, since the intention is that the planner can investigate the effect on the "optimum" of changing the relative weights of the trade-offs between accessibility and living space. Nevertheless, as was noted in the review of empirical studies, the impact of particular transport changes is often constrained by land-use planning decisions taken in conjunction with the transport scheme, and these decisions themselves may be based on rather narrow notions of 'optimality'. To this extent, urban development does not depend freely on the locational preferences of its inhabitants. Nevertheless, as was noted in the review of empirical studies, the impact of particular transport changes is often constrained by land-use planning decisions taken in conjunction with the transport scheme, and these decisions themselves may be based on rather narrow notions of "optimality". To this extent, urban development does not depend freely on the locational preferences of its inhabitants.

All the models mentioned above, with the single exception of the Amersfoort model which is still in preparation, contain a model of the transport network in addition to the model of location. Once the locations of people, jobs and facilities have been predicted on the basis of the accessibility and attractivity of the zones, the trips from each area can be predicted and loaded onto the network. In all models, except the Leeds model, the network is capacity-constrained, so that changing the flows on the network will change the average travel times as the level of congestion varies. Since the accessibilities are a function of the travel times, the process of achieving equilibrium is iterative. The TRANSLOC/TRAMA models are interesting in that the transport network is designed endogenously as the land is allocated and developed.

Most of the models considered two modes, public (transit) and private automobile, though at the moment the Toronto model assumes a constant modal split and is therefore insensitive to policies which affect public and private modes differently. The current version of ITLUP bases its accessibility measures on average travel times only, and does not distinguish between public and private transport, though there has been some preliminary work on incorporating modal split. The POLIS model combines transit and walking into one compound mode, with car travel as a second mode, but in the Dortmund model the present emphasis is on investigating the locational implications of economic change, so that the detailed transport sector originally envisaged for the model has not yet been incorporated, and the accessibilities are based only on average interzonal travel times. The ARC models have handled several modes. In various applications these have included automobile, bus, train, metro (rapid transit), trolley and walking for passenger travel, and freight carriage by road, rail, and water. For investigation of public transport policies the omission of walking from most of the models can be a serious drawback, since for bus travel especially the most important competition often lies between walking to a local destination and taking the bus to a more distant, but more attractive, destination.

Other Work

Although the underlying mechanisms of these operational models are fairly simple, it will be appreciated that by the time they have been linked together into a system which often involves several levels of iteration, based on a matrix of some dozens of zones and a transport network containing a large number of links with disaggregation by employment type, housing type, socioeconomic group, etc., the models assume a very complicated appearance. The account of them given above is necessarily very superficial. Moreover, the models in current use are not complete and unchangeable entities, but are constantly being developed at the same time as they are applied. The structural framework of this type of model is also being improved: for example, Boyce[35] is developing a consistent framework for simultaneous estimation of location and the travel interaction, to avoid the usual iteration, and similar considerations are also being tackled by Los[36] in the construction of an operational optimising model. In addition, the separate components of urban modelling are receiving attention from various researchers.

Other models have adopted approaches to the problem of predicting urban development which are quite different from those described above. Some of these are primarily economic models with no detailed transport sector, and others, like EMPIRIC,[37] contain no explicit behavioral mechanisms but rely on establishing relationships between the many factors involved by regression analysis. Cordey-Hayes and Varaprasad[38] have studied population movement and modal split in the area around London, at a very coarse level of detail, using a model based on logistic growth curves which are modified by travel costs and migration rates.

A particularly interesting approach has been developed by Allen et al. at the University of Brussels,[39] whereby the usual trade-off between accessibility and space, plus the predilection of similar social groups to congregate together, is subject to random fluctuations, or inhomogeneities, which quite by chance can change the direction of development. The dynamic self-organising nature of a city's development is thus represented by an evolution which is generated by a series of instabilities, so that future development from a particular point in time might take any one of a number of paths, and the path actually taken can only be predicted in terms of probability. The modelling has been applied both to the distribution of towns and cities in a region, and to the evolution of a single urban centre. Although the results are qualitatively plausible, this approach is very new, and it is still some way from being usable for any detailed policy assessments.

The work of Zahavi on travel "budget" models[40] should also be mentioned here, because even though they are currently geared to predicting total travel and modal split within the entire city area, potentially they could be developed to make predictions about the distribution of destinations and therefore about land-use patterns, using a basis which is entirely different from the behavioral mechanisms discussed so far. Zahavi's models are based on the observation, that for a given household type, the average values of the total time spent travelling, and the fraction of household budget spent on travel, are remarkably constant across a wide range of situations from areas with low density, dispersed facilities, and poor transit services to big city conditions where densities are high, facilities concentrated in the core, and transit is good. Considerable improvements in average travel speeds seem to have been used to travel further, spending the same amount of time in total, rather than to spend less time in accessing the same destinations as before. Thus, achieving as wide a choice of destinations as possible seems to be an important component of people's travel behavior, and this is an aspect which is not properly represented by conventional models (though it is interesting to note that TRANSLOC's objective function is formulated to give explicit recognition to the value of a wide choice of destinations). Certainly, model parameters can be adjusted to ensure constancy of total travel time and if this is done, as Bland[41] has shown, the results are markedly different from those achieved with constant parameters, but such an arbitrary adjustment is unlikely to be satisfactory. Variation of these parameters is equivalent to varying the trading-off of one desirable attribute against another, and of course as one attribute becomes more freely available than another, it does seem plausible that the trading rate will change. If so, this would emphasise the caution with which any comparison of one urban configuration with another should be treated, since the intricate trading between a variety of desirable but conflicting attributes suggests that, if the "quality" of a town can be measured at all, a whole host of different indicators will be required.

Applications of Urban Modelling

Apart from the Amersfoort and Toronto models, which are still being developed, all the "operational" models described in the previous section have been used in policy evaluation. The current version of the ITLUP model[23] has been applied to the San Francisco Bay Area to examine the effect of introducing new highway links, changing travel costs by increasing or decreasing parking changes, bridge tolls, highway speed limits and fuel planning consents for various levels of population density in certain areas. The location sub-model (DRAM) has also been applied to the St. Louis/ Minneapolis conurbation to see the effect of changing the amount and type of housing in different areas, and of changing the accessibility of particular zones.

The Leeds model has been used to examine the effect of changing travel costs by means of parking fees, fuel prices and transit fares, and by changes in overall speed and modification of the transit network.[42] In particular, the effect of various transport and land-use policies on depressed inner-city areas has been studied. The same model has been used also to predict the effect of a suburban hypermarket on travel and land use in Harrogate, a relatively small town. At the moment, the model is being modified considerably to represent a commuter corridor into London, including road and rail travel, in order to examine the long-term effects of different fares policies.

The ARC model has been used in a variety of forms for many different applications. Most extensively, it has been calibrated to Sao Paulo[24] in Brazil and used to assess planning policies which favoured growth in the surrounding region rather than in the city itself, and various transport policies concerned with rail tariffs, road tolls, and highway and waterway investment aimed in particular at diverting freight carriage from one mode to another. In Tehran,[43] a different version of ARC has concentrated on passenger travel in a study of the effects of building a metro or improving the highway network. Changes in parking costs and transit fares, and in various development control policies (including subsidised housing and taxes on employment) were also investigated. The latest applications have been in designing the Argentina National Transport Plan, and in a land-use study for Bilbao, Spain.

POLIS has been applied to Cologne, Vienna, and Darmstadt and used to examine several hypothetical land-use policies, largely as a demonstration or training exercise.[31] Different distributions of development, from concentration in a high-density corridor to incremental development around local centres, together with different levels of highways and transit investment, have been studied. The model has also been used to investigate the locational impacts of new fixed-rail transit technologies in the Karlsruhe area.

TOPAZ has been applied to several Australian cities,[33] most extensively Melbourne, and more recently to Tehran[44] as an alternative to the ARC model. The policies tested in Tehran were the same as for ARC, while in the Australian applications different levels of transit service and highway investment, and different population and employment distributions, have been examined. The World Bank has also applied TOPAZ in studies in Seoul, Manila, and Jakarta.

TRANSLOC has been used in conjunction with the transport model TRAMA to examine the long-term options arising from two different development plans for Stockholm.[34] The two plans contained different distributions of jobs and homes and different detailed improvements to the public transport system, though they were not radically different from one another. TRANSLOC has also been used to investigate the effect of releasing for development the land occupied by a redundant airport in Stockholm, and to study the trade-off between space and accessibility in Gothenburg.[45] TRAMA has also been used in an interesting study of six different land-use patterns for the Stockholm area, ranging from arrangements where all employment was in central Stockholm to arrangements where each area of the Metropolitan Region was self-sufficient in jobs. The model predicted that total travel time would vary by less than 10% and modal split (public/private) by only 5% from one extreme to the other. Within this apparent insensitivity, however, the travel patterns with decentralized employment would have a profound effect on use of the metro system, since work travel to the central area would be cut by 50%. This perhaps makes the point that, while the land use/transport interaction may not seem to be strongly in evidence at a very aggregate level, at a finer level of spatial detail, the implication for the way in which the city will function can be very profound indeed.

The Value of Modelling

In reviewing the predictions of the various models, little more can be said than that most of them seem to be plausible. In general, increased travel costs lead to greater centralisation, lower costs to more dispersion (though Mackett also finds that fare-free public transit can encourage employment to centralise to take better advantage of the centre-oriented route network[42]). For the most part, the various models have not been applied to sufficiently similar situations to permit many useful comparisons, but from the reported results it seems that in ITLUP residential location is more sensitive to transport costs than is employment, while the converse is true in the Leeds model. There are also differences in the reported results of the ARC and TOPAZ models applied to Tehran, though the overall conclusions are similar regarding the justification for investment in a metro system or a freeway network. A proper comparison would be valuable. Putman[30] has made a direct comparison of EMPIRIC and DRAM as applied to Minneapolis-St. Paul, but since EMPIRIC is not behaviorally based, the comparison sheds little light on the success or otherwise of the "behavioral" mechanisms in DRAM. EMPIRIC was able to reproduce the observed evolution slightly better than DRAM, but DRAM was more responsive to the application of different policies than was EMPIRIC. Certainly, it is reasonable to expect that models based on mechanisms which emulate behavior will be better able to handle policies which diverge appreciably from previous practice than will models based solely on statistical fitting to observed trends, but of course the reliability of the predictions will depend on the adequacy and realism of the mechanisms assumed.

And herein lies the problem. Given the large numbers of parameters included in these models, it is obviously possible to reproduce the observed behavior without necessarily building into the models reliable predictive mechanisms. The difficulty is that there is no satisfactory way of testing the models across the range of policies they were designed to assess. Evolution of land use takes place very slowly, and even if it were possible to identify unambiguously the effects of individual changes (and the review of empirical studies illustrates the difficulty of this in the face of all the other changes which occur at the same time), the range of situations available for examination in any one place at any one time is extremely limited. Mackett has attempted to use his model to map the evolution of Leeds from the turn of the century to the present day, but the data available from the earlier periods were not sufficiently detailed for this to act as a very discriminating check on the validity of the model.

Though the working of the models seems plausible, this is not enough. We have too little knowledge on which to base our expectations about the size of these effects. Because the overall response to a particular change is the sum of many conflicting interactions, it is important to set the parameters involved in each interaction very accurately if the net effect is to be predicted realistically. Meanwhile, work proceeds on improving the modelling in terms of attaining a greater theoretical consistency, or mathematical simplification or rigour, or by trying completely new approaches. It is good that these advances should be made, but it seems there is some danger that the work will proceed in isolation from proper assessment of what the present models are worth in practical terms.

Since the full predictions of the models are so difficult to test on any practicable time scale, two other approaches may help towards such an assessment. One is to compare the working of the various operational models by running them on comparable data sets and under the same policies. There seems to be sufficient variety in their formulation and detailed construction to ensure that this will not be a sterile exercise in comparing models which all embody the same mistakes. The predictions of all of them are likely to be somewhat removed from reality, of course, but an investigation of their differences could well be enlightening and might enable conclusions to be drawn about the realism of some compared with others. It is perhaps inevitable that, because the models imitate a set of circumstances with which the modeller is usually personally familiar, urban models take on a life of their own, and interpretations of their predictions are not always tempered by an appropriate amount of reasoned scepticism. There is a tendency to explain unexpected results in terms of the behavior of the inhabitants of the city instead of in terms of the content and structure of the model. Comparison of several models could provide a more stringent assessment of their realism. The U.K. Transport and Road Research Laboratory and the U.S. Department of Transportation are currently engaged in setting up a study of this kind, and it is hoped that a detailed investigation and comparison of a number of these models will be possible.

A second approach to assessing the value of the models is to enlist the considerable experience of urban and transport planners in criticising the forecasts of the predictive models, or in assessing the usefulness of the optimising models, so that where implausibility exists it can be thoroughly investigated. The sort of knowledge required exists in planning departments around the world, but normally it is divorced totally from the mathematical approach of the modellers. Where good empirical studies of particular schemes exist, of course, it would be valuable to compare the predictions of models set up to represent the same situation. But even though much of the existing experience is qualitative rather than quantitative, given the will to cooperate between modellers and planners, considerable light could be shed on the inadequacies of current modelling. Unfortunately, the surge of modelling work in North America in the 1950s and 1960s was rapidly eroded as the potential users grew sceptical about the claims of the urban modellers. Problems of calibration and computation forced over-ambitious models to be simplified radically and, given the newness and lack of experience in the methodology, it is hardly surprising that many models never became operational, or failed to live up to the claims initially made for them. Disenchantment was doubtless partly due to over-enthusiasm on the part of the modellers, but it was also a result of a lack of understanding on the part of the users, who did not appreciate the limitations of a technique which was in its infancy. This scepticism is unfortunate, because the development of urban models is an evolutionary process which will take longer to reach fruition if poor performance by the necessarily rudimentary first stages drives away support for improvements which will, hopefully, make the tools more reliable and more useful. The problem is not primarily one of waiting for someone to come along with the "right" formulation, nor of collecting more or better data (though this would help in some aspects), nor of bigger and faster computers. Progress would seem to depend more on proper evaluation of the formulations which exist, and then refining or replacing them in the light of the experience of those planners who can best use the results.

In Conclusion

With the perspective of history, the impact made on urban development by the introduction of mechanized transport is quite clear. The greatly improved speed and accessibility provided by public transport and the private automobile have enabled cities to spread and densities to fall. In more recent times, however, studies of transport changes have been greatly complicated by the many other changes which confuse the interaction between transport and land-use, and although there can be no doubt that transport schemes can facilitate and encourage new urban development, it seems that many other factors are important and must be taken into account. Perhaps partly because of this difficulty of identifying unambiguously the relationship between transport and land-use, and partly because of scepticism that the very complex mechanisms can ever be reliably modelled or predicted, those who advise on transport and planning have often been reluctant to encourage analysis and modelling in this field.

In some quarters there seems to be a belief that, in practice, the land-use implications of transport policy are unimportant, or at any rate that they will be so in a future where major investment in urban transport (both private and public) is likely to be severely curtailed by a harsher economic climate. Yet the historical evidence clearly demonstrates that, potentially at least, transport changes can make a major impact on patterns of urban development. Even policies as simple as a transit fares change have long-run effects which are likely to appear as changes in activity patterns and land-use effects which are likely to appear as changes in activity patterns and land-use patterns. At the moment, many investment and operating decisions have to be made largely on the basis of their short-term impacts which, although they can generally be predicted fairly reliably, may have little bearing on the ultimate result. Without a knowledge of how the ripples raised by a particular policy may spread throughout the urban form, policies which seem sensible in the short term may backfire in the long term, and decisions made now may generate future urban patterns which prove undesirable and irreversible.

Mathematical modelling attempts to assemble the complicated interactions which underline urban development into a rational and predictive system. However, the present generation of urban models is still largely experimental: its models are unproven and probably unreliable. Because they can include only some of the considerations involved in predicting and evaluating urban performance, their results have to be interpreted with particular care. Even if the modelling process can be vastly improved, decisions will still need to be based on wider aspects than those treated in urban models, and local experience and intuition will always have a major role to play in interpretation. Consequently, the limitations of models should be clearly understood by those who use them.

Despite those limitations, however, modelling deserves support now, even if it cannot yet provide reliable answers, because it provides a disciplined approach to assembling the available knowledge and experience into a systematic framework. The available choice is not between accepting or rejecting modelling, for even ad hoc planning and transport decisionmaking rests on assumptions about the likely effects of particular courses of action which are akin to modelling. The "model" for such predictions is a personal one which may be the result of long and hard-won experience. It may be very good, but unless the knowledge embodied in it can be quantified and set down in a consistent way, no matter how empirically, the "model" will be lost with its owner and no progress will have been gained. By making this knowledge explicit in a quantitative model, contradictions and implausibilities can be removed and other people's experience built in. For the most part, of course, the people with an extensive experience of planning are not in a position to build such a model directly. Nevertheless, by assessing such models as there are, pointing out defects and suggesting aspects for improvement, their understanding can make major contributions to model development. In the long run, this approach offers the best hope for gaining a deeper and more quantitative understanding of the complete mechanisms involved. Without it, all the experience gained will remain fragmented, and planning will continue to rely on intuition and rule-of-thumb which, in the final analysis, remains as untested as the modelling.

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TRANSPORTATION SYSTEMS AND URBAN FORM: PERFORMANCE MEASURES AND DATA REQUIREMENTS

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Abstract

Transportation/urban form relationships have long formed the backbone of our knowledge about the growth and development of urban areas. The present paper reviews this knowledge briefly to provide a background for exploring recent transportation/urban form relationships, their measurement, and data needs.

A key theme of the paper is the changing nature of the urban environment since 1970. Prior to this date transportation investments and policies were geared to forecasts of urban form and development. However, in the post-1970 era things have changed dramatically. Increasingly transportation is envisaged to be a means for shaping urban growth and form into more efficient and desirable patterns.

With this shift in roles for transportation in urban areas comes a need to reevaluate the measures that we have used in the past to monitor urban form and transportation systems performance. This paper sets out a number of emerging needs and suggests new, more detailed measures of both urban form and urban transportation systems. These measures are much more fine-grained and able to describe form and transportation system changes at the level of a city block.

The 1980s, it is suggested, will continue where the 1970s left off, and we must be fully cognizant of the changed urban and economic environment in order to appropriately understand the emerging relationships.

Introduction: Overview and Principal Themes

Transportation and urban form relationships occupy a central position in our understanding of the evolution and development of urban areas. Early in the nineteenth century Johann von Thunen noted the relationship between transportation costs and the most efficient layout of land uses on a large agricultural estate in Germany.[1] Less than a century later Richard Hurd and Robert Murray Haig developed parallel ideas about the interaction between transportation and land use/land value. They also strove to identify the impacts of changing patterns of transportation and changing transportation technologies upon urban land uses, land values and rents. Finally, in the mid-1960s, William Alonso synthesized these complementary views of the transportation/urban land interaction and provided us with a central focus.[2] Essentially, this synthesis points out the complementarity between transportation expenditures and land values and rents. It builds on this complementarity and on the differential need of different urban activities for centrality to develop a familiar pattern of land uses, where highest density uses cluster around nodes of highest accessibility, and less demanding activities fill in behind these in a series of rings away from the high accessibility points.

In the Alonso framework, as well as in the most recent work in the "New Urban Economics," the role of transportation systems and costs in shaping urban form and development is central.[3] It is also explicit.

Less explicit, but nonetheless central, is the role of transportation in the classic descriptive "models" of urban form by Park and Burgess, Homer Hoyt, and Harris and Ullman.[4] The oldest of these (that by Park and Burgess) dates from 1925 and describes the evolution of urban form against a backdrop of early public transportation and pedestrian access. Homer Hoyt's work from 1939 extends the Park-Burgess concentric ring theory of urban form to look at sectors or wedges in these rings in an era of public transportation and the rise of automobile-based suburbs. By 1945 it was becoming clear that the automobile was to be a major shaper of urban form. The Harris-Ullman "multiple nucleii" view of urban form expressed this clearly: instead of a single urban center, urban form is best viewed as a series of interconnected subcenters.

Knowledge of transportation/urban form interactions provided important background for the massive investments in urban transportation systems during the 1950s, 1960s, and early 1970s. During this period the important linkages were between the emerging pattern of land uses and the resulting pattern and volume of trips. Land use and urban development were viewed as generators of demand for transportation systems. Transportation system planning started with forecasts of urban development and land use patterns. Since the early 1970s there has been a reversal in thinking; and transportation, particularly public transportation, is seen as a key ingredient in shaping urban form rather than merely following it as in the pre-1970 period. This reversal provides the central theme of this review paper.

Specifically, transportation investments are no longer viewed as being determined by land use patterns and preferences. Rather, transportation investments are now being depicted as having considerable promise in shaping and consolidating existing urban forms. It will be argued below that such a shift requires some rethinking about the means by which we measure transportation and urban form interactions. New measures and methods of necessity imply new data sources which will also be noted below.

To get at these new measures, as well as the review of extant measures, we will first review the changing environment within which urban transportation planning is taking place and is likely to take place in the future. We will then move on to explore transportation/urban form relationships and their measurement in the pre-1970 environment and in the new, largely post-1970 environment. The data needs of these quite different environments are assessed against these changing interactions. The paper concludes with a brief summary and look into the future to try to foresee some of the emerging issues in the transportation/urban form causal chain.

The Changing Context of Transportation Planning: Some Background for Understanding Transportation/Urban Form Interactions and Their Measurements

With the advent of the 1970s, Western developed economies appear to have entered a qualitatively different period of economic and urban development. Gone are the days of rapid economic growth, price stability, full and growing employment, resource and energy abundance, and most significantly, gone is the economic optimism of the pre-1970 period. The buoyancy and economic growth of the earlier period have been replaced by environmental concerns and environmental protection, growth controls, and efforts to consciously manage and efficiently utilize scarce capital, energy and natural resources.[5]

Given this very different economic milieu, it is not surprising to discover very different strategies emerging for the future growth and development of our urban areas. For example, we see much greater concern for the maintenance and rejuvenation of existing urban capital, from older housing through the aging urban infrastructure. The emphasis is on management of extant resources rather than the former push to build anew. There is evidence of the long awaited return of the middle-class to central cities, as well as a growing preoccupation with conserving scarce energy, land and open-space resources.

Against such a backdrop, the urban transportation planning process has changed dramatically. Transportation planning has recently stressed management of transportation resources to complement new investments. New investments themselves have been scaled down with greater stress on public transportation improvements. Long-run comprehensive transportation and urban planning have been replaced with much shorter range incremental planning.[6]

In short, the 1980s are shaping up to be very different from the 1960s and the early 1970s. These differences must be kept in mind when we turn to the examination of transportation/urban form interactions which follows immediately, since the differences between the periods imply very different measures of transportation/urban form interaction, and indeed very different interactions themselves. Let us look at these interactions and the methods and measures used to explore them. Our review will be comprised of two parts: the pre-1970 period and the post-1970 period. Such a dichotomy allows us to relate changing urban environments to changing urban form/transportation interactions and the need for changing measures to monitor and assess these interactions.

Transportation and Urban Form: Linkages and Measures

The Pre-1970 Era: From Land Use to Transportation Investments

Starting in the late 1950s in the United States urban transportation systems planning (largely freeways) came to be closely linked with forecasts of urban form and land development. We will draw heavily upon this U.S. experience since it rapidly became a model for much of the urban world, though we will note exceptions where needed. The transportation planning process in this era began with forecasts of urban form and then moved on to translate these urban forms into travel demands and ultimately into forecasts of transportation system requirements and investments.

Among the most common of the measures of urban form and development were the following:

- Employment by type of employment (usually at the two-digit SIC level of disaggregation) and by location within the urban area (usually census tracts or traffic zones);
- Land use by type of use (several classes of housing, employment by SIC, and public and vacant uses), and by location as above;
- Households by income, size, age of the head of the household (all which corresponded closely to land use above in the ideal), and once again the location within the urban area of these households;
- Population ideally by age, sex, occupation, and industry of employment and by location again.

To generate such forecasts heavy use was made of both comprehensive and partial models of land use and urban development. The EMPIRIC and PLUM models are examples of the former, while the Chicago Area Transportation Study (CATS) is an excellent example of the latter.[7] Informal "models" and local expert knowledge were also drawn upon freely.[8] The results were a set of usable forecasts of urban form, development and land use which could then serve as inputs to formal transportation system models which were used for assessing future transportation system performance and requirements.

Among the most common measures of the urban transportation system and its performance , all of which were forecast given the previous estimates of future land use, employment, and housing by location within the urban area were the following:

- The number and type of trips;
- The distribution of trips across the transportation network;
- Mode split;
- Congestion and capacity requirements by specific links among the nodes of the network;

- Speeds by mode on the network and/or travel times or costs ideally by the hour of the day and to and from different traffic zones within the system.

The causal link in all of the pre-1970 transportation planning went from land use and urban development to transportation facilities planning. Transportation facilities followed the forecast of urban forms. The 1970s brought in a different causal chain as we see next.

The Post-1970 Era: Transportation as a Guider of Urban Form

With the advent of the previously noted changes in the world and urban economies, a new and different era for transportation and urban planning emerged. With the shift toward stewardship and maintenance of our urban environment and its capital stock came greater interest in using transportation investments and management strategies to bolster desired urban forms, most notably more compact forms with greater efficiency of land, capital, and energy utilization. The key was seen as the rejuvenation of older downtown areas, not just of large cities but also of smaller non-metropolitan places in light of their rapid and unexpected growth beginning in the early 1970s.[9] In the atmosphere prevailing during the 1970s and beyond into the 1980s, transportation system improvements were viewed as being prerequisites or co-requisites of urban revitalization. In this view transportation can play a role in reinforcing existing urban forms and shaping them at the margin to be more consistent with growing energy, land, and capital constraints.

Previously noted measures of the urban transportation system and its performance need to be augmented by additional measures which include the following:

- Details on planned transportation investments by mode and capacity;
- Details on the routing of the investments, including details of planned technologies to be used for public transit investments to provide measures of environmental quality and impact;
- Station and/or interchange locations including precise sitings of stations and modal interchanges within several meters accuracy;[10]
- Parking locations and capacity, cost again within meters of actual siting;
- Details on modal interchanges, including the types of modes, their scheduling, capacities, etc.;
- Energy requirements of various transportation system proposals;
- Environmental impacts of proposed systems.

Note that the foregoing requires a level of micro detail that was not needed in the earlier era. Such detail is required because of the explicit desire to use transportation to effect efficient land uses, and because recent experience has pointed out how critical are such micro-spatial details.[11]

The requirement for much greater micro detail carries over to the measures of urban form that are needed if we are to successfully use urban transportation investments as shapers of form. Specifically, in addition to the previously noted measures of urban form, urban planning needs information about transportation impacts and about the current state of the following:

- Land uses (including mixed uses) that are encouraged and discouraged by transportation investments, particularly public transit and freeway redesign;[12]
- Population and household types that will be shifted as a result of changing transportation patterns;
- Employment types that will be attracted/repelled by transportation investments and population/household movements;
- Local area zoning details by small area, particularly near public transit stations and modal interchanges;
- Development and maintenance cost estimates of various resulting urban forms;
- Forecasts of building permits by use, value, timing, and small area location to enable planners and investors to assess the "climate" and level of urban development activity in small areas;
- Building and development densities to accompany investment estimates to provide measures of urban form again at the micro scale;
- Environmental impact estimates of the ensuing urban development and the environmental costs and benefits of alternative urban forms;
- Energy needs of alternative urban forms, both for construction and maintenance.

Once again, emphasis has shifted to smaller spatial scale necessitated by past experience, and also by the growing concern for preservation and revitalization of existing urban forms and unique urban habitats, including individual structures, indeed a micro level of planning detail. The methods to be employed in carrying out such urban form estimates based on alternative transportation investments and policies will, of necessity, be different from extant methods though it is likely that extant methods will be a starting point.[13] Greater use of sketch plans and short-term methods appears inevitable. A return to physical planning methods is also highly probable.

Data Sources Past, Present, and Future

One of the early limitations of pre-1970 transportation and land use forecasting methodologies was the existence of spatially disaggregated data. Rapid developments in computing machinery and the emergence of large-scale transportation and land use planning activities for virtually all of the major cities in the Western world have obviated earlier concerns. As a result, in 1981 we find that there is an ample data base in most cities to enable transportation and land use planning to proceed with quite sophisticated methodologies. Specifically, most cities possess the necessary spatially disaggregated data alluded to earlier. We now know a great deal about the spatial distribution of land using activities in urban areas as well as some of the underlying locational and behavioral rationale for these spatial distributions. Similarly, an enormous body of transportation data exists allowing us to have important insights into the current state and performance of our urban transportation systems and also about forecasting future states of these systems given our understanding about travel behavior. Local planning and transportation agencies are the depositories of most of these data, although national censuses have also provided much more spatial disaggregation than was available during the 1950s and 1960s. So much for the past.

The emerging transportation/urban form relationships of the post-1970 era required very different and much more micro-spatial detail. Much of this data also exists from the breakthroughs of the 1960s and 1970s. However, much more needs to be done, particularly at the scale of city blocks. Perhaps building-by-building inventories will have to be assembled out of tax and planning permit records. Building permit by use and value will also have to be spatially disaggregated to the block level. In short, the need exists to disaggregate the extant data to the next level of spatial detail: from the traffic zone or census tract down to the city block or smaller. Our past successes in disaggregating urban area data down to smaller and more usable spatial units should stand us in good stead as we use sound data handling and sampling methods to step down to an even finer spatial scale our knowledge of land using activities and of the transportation systems that serve them. In this way we can build the kinds of transportation/urban form relationships dictated by the needs of the 1970s and 1980s--relationships which depend on the micro-spatial interaction of transportation and urban form.

Summary and Conclusion

This brief review has stressed that significant changes are appearing in urban transportation and urban form linkages. Increasingly, transportation is seen as a means for guiding urban form toward more efficient and higher quality living and working patterns. These emergent changes have significant implications for the means by which we measure and monitor transportation/urban form relationships. We need additional methods and data sources to drive these methods. We also need to develop a renewed sense of the two inextricable links between urban form and urban transportation systems, both at the macro and micro scales within and among urban regions. Such a renewed sense and commitment to greater understanding has been a principal goal of the present overview.

NOTES

1. Johann von Thunen, *The Isolated State*, Germany: 1826.

2. William Alonso, *Location and Land Use* (Cambridge, Massachusetts: Harvard University Press, 1964). Alonso's book also gives an excellent summary of much of the earlier work by Hurd, Haig, etc. For a classic statement of the relationships between urban growth and structure and transportation improvements see Richard U. Ratcliff, *Urban Land Economics* (New York, New York: McGraw-Hill Book Company, 1949).

3. Edwin S. Mills, *Studies in the Structure of the Urban Economy* (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972) sets out the basics of "the new urban economics." Mills, as one of the founders, is well qualified to state the case in which transportation plays a central role.

4. Alonso, *op. cit.*, succinctly describes these early models. More complete discussions can be found in Larry S. Bourne, *The Internal Structure of the City*, (a collection of edited readings, New York, New York: Oxford University Press, 1971).

5. These points are covered in some detail as they relate to strategies and structures of urban systems modelling in Michael A. Goldberg, "The Technology of Urban Systems Modelling: Nagging Questions, Sagging Hopes, and Reasons for Continued Research," in Bruce Hutchison and Michael Batty, editors, *Urban Systems Modelling*, forthcoming (London, England: Plenum).

6. The emerging transformation in urban transportation planning and its environment are discussed in detail and interesting insights in Douglass B. Lee, Jr., *Improving Communication Among Researchers, Professionals and Policy Makers in Land Use and Transportation Planning* (Washington, D.C.: U.S. Department of Transportation, 1977).

7. Two excellent reviews of the literature are available to sketch out the nature of these and other related transportation and land use models. See: William Goldner, "The Lowry Model Heritage," *Journal of the American Institute of Planners* 37(1971): 100-111; and Stephen Putman, "Urban Land Use and Transportation Models: A State of the Art Summary," *Transportation Research* 9(1975): 187-202.

8. This point is stressed in Janet R. Pack, "The Use of Urban Models: Report on a Survey of Planning Organizations," *Journal of the American Institute of Planners* 41(1975): 191-199.

9. For details see: Niles M. Hansen, *The Future of Nonmetropolitan America: Studies in the Reversal of Rural and Small Town Population Decline* (Lexington, Massachusetts: D.C. Heath, 1973). The world-wide nature of this phenomenon is discussed in B.J.L. Berry, editor,

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10. The study of the Bay Area Rapid Transit system taught us much of what we currently know and need to know, about developing transit systems and allowing for appropriate land use planning in conjunction with them. For an excellent summary see, Michael V. Dyett and Emilio Escudero, "Effects of BART on Urban Development," *Transportation Engineering Journal* (May 1978): 239-251.

11. See details of BART study: John Blayney Associates and David M. Dornbusch and Co., *Land Use and Urban Development Project Study Design and Implementation*, Report to the Metropolitan Transportation Commission, Berkeley, California, March 1977 (Berkeley, California: Metropolitan Transportation Commission, 1977).

12. A host of recent work has focused on these and related issues of transportation and urban development and redevelopment stimulation. See for examples: Michael Meyer, *et al.*, *Urban Development and Revitalization: The Role of the Federal and State Transportation Agencies* (Cambridge, Massachusetts: The Transportation Systems Center (1979); Robert Hicks and Michael F. Kobran, "Transportation's Role in Downtown Detroit Revitalization," *Traffic Quarterly* 33(1979): 331-346; Paul E. Potter, "Urban Restructuring: One Goal of the New Atlanta Transit System," *Traffic Quarterly* 33(1979): 45-60; Douglass B. Lee, Jr., "Evaluation of Economic and Development Impacts of Major Transit Investments," (Cambridge, Massachusetts: U.S. Department of Transportation, Transportation Systems Center, (1981) (Mimeographed); and finally, David Segal, "The Economic Benefits of Depressing an Urban Expressway: The Case of Boston's John Fitzgerald Expressway," (Cambridge, Massachusetts: Graduate School of Design, Harvard University, December 1980). (Mimeographed).

13. See Lee, *Improving Communication,...*, *op. cit.*, for interesting details of emerging requirements of transportation and land use planning for urban areas.

TRANSPORT SYSTEMS AND URBAN FORM
A FEDERAL VIEWPOINT

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Abstract

In spite of the long-standing realization that transportation system evolution is intimately related to land use and the nature of urban form, a comprehensive understanding of the complex hierarchical evolution of the urban area is at a primitive state of development. This paper describes how research at the U.S. Department of Transportation's Transportation Systems Center, taken together with research from around the world, leads to an initial framework for understanding some of the major issues currently being reflected in the emerging policies of the Federal government. In particular, an understanding of some basic aspects of transportation systems and urban form has important implications for policy issues in Federal programs for mass transit, energy conservation, and industrial policy.

Introduction

The Federal roles in urban affairs and the Federal activities in influencing the distribution of resources and authorities to urban areas are justified on the premise that urban growth and vitality are fundamental to national growth and economic development. In recent decades, growing realization of the threats to well-being from pollution and to stability from energy shortages have focused attention on the issues of transportation and urban form. In the coming decade all these issues will come into sharper focus as hardening economic constraints will force us to think more deeply about what causes what in urban societies and where our national priorities truly lie.

This paper presents a conceptual framework for many of the key issues in transportation policy that are related to issues of urban form, discusses the basic findings of the last seven years of research at the U.S. DOT's Transportation Systems Center that relate to these issues and sketches some of the implications of our work.

Background

Earlier workshop sessions will have addressed the subjects of the state of the art and performance indicators and data requirements. From our perspective as DOT's in-house research organization, there are huge masses of data; the state of the art in making sense of it all is primitive, and the data and performance indicators are often unreliable, confusing, and internally inconsistent.

Furthermore, the policy issues and the implications one draws in viewing the knowledge base from the policy perspective are highly dependent upon the position and viewpoint of the individual. For example, a real estate developer may be concerned with different aspects of transportation and urban form than a city mayor, a regional planner, a governor, or a DOT official.

We must put more thought into the relevant concerns at each level of government hierarchy and how these concerns relate to one another and to the analyses that support each level of concern.

We know in a general way that transportation is closely related to land use and density of settlement.[1,2] The faster we can go, the more spread out we can be, all other things being equal.

In our research at TSC we have concentrated on several specific aspects of urban form, the first of which is the spatial distribution of macroscopic densities of residences, employment, income, car ownership, and related concerns. At suitable macroscopic scales, we find residential densities to be exponentially declining with distance from the center of the city.[3] This result is expected from simple theories[4] as a consequence of transport cost being proportional to distance, and density distributions being a result of cost constraints on the distribution of the urban population. We have also observed a general diffusive growth behavior of almost all U.S. cities studied. As a result, average central residential densities decline as cities grow at their periphery. Such a result is consistent with theoretical expectations as transport costs decline in real terms and average speeds increase. If these trends continue (and we expect they will), they will continue to have profound implications for public transport potentials and for the spatial structure of government at the urban level.

Our studies of employment distribution[5] are not as extensive but indicate similar macroscopic exponential decline. The trends in central density are more variable and clearly are more dependent upon other non-transport economic factors.

Income distribution is highly correlated with residential density[6] usually rising as one moves away from the city core to a peak in the moderately distant residential rings and dropping as one approaches the rural fringes. However, several cities have well-to-do central cores.

Car ownership[7] is clearly related to density and income. Cars are not convenient to own in very dense areas, nor are they as necessary. In most U.S. suburbs and rural areas, cars are clearly a logistic necessity.

Fine structure issues in urban form involve the competition for space by land use categories and human characteristics like ethnicity that structure the specifics of a given neighborhood. Other identifiable fine structure influences are geography and climate (e.g., hills, swamps, lakes, prevailing winds) or historical infrastructure decisions or evolutions (e.g., where to put a subway station, a luxury residential area or a garbage processing plant, or larger scale impacts of small cities or towns assimilated into a large metropolitan structure). In general, Federal perspectives ignore fine structure issues or treat them in the context of equity and due process issues.

Our research for DOT is now reaching a point where we begin to see how to model the evolution and growth of metropolitan areas at the fine structure level of detail.[8] We believe that transportation does play a signficant role at this level as well as at the more macroscopic level. Indeed, local interests may well be more interested in this capability.

Finally, there is another aspect of urban form, city size itself, that we believe to be strongly influenced by transport systems. The exponential density relationship yields an analytical city size estimate free from the ambiguities of political or threshold density definitions of urban areas. With models similar to the urban model we have seen how intercity transport systems impact the regional distribution of the national populations.[9] Our studies have shown that the rate of regional migrations is directly related to the improved speeds of transport made possible by the evolution of transport technology.[10] Analysis of two hundred years of time series data of U.S. city size distributions[11] shows that the natural process of urbanization is nearly saturated in this country, and that since the 1930-1940 period a national preference for life in cities of between 10,000 and 100,000 people is beginning to emerge in the statistics of city sizes. That preference implies a general recognition (increasing over time) of diseconomies of scale in large cities, a fact worth pondering in the formulation of national transportation policy.

Policy Issues and Implications

Mass Transit

The foremost policy issue historically within DOT has been to determine the character and level of Federal support to mass transit. Capital subsidies to urban public transportation were initiated under the programs of housing and urban development in the early 1960s, but did not reach significant levels until the formation of the DOT Urban Mass Transportation Administration in 1968. The bulk of the capital subsidies have gone to finance rapid transit modernization, extension, and new starts. Significant sums have gone to support standard bus operations and some R&D has gone into service innovations or new systems technology potentially capable of serving moderate-to-low density service areas.

The rallying cries for this effort have varied from: "reverse the decline of mass transit!" to "let's demonstrate what modern technology can do!" to "revitalize our (center) cities!" or "conserve energy!" But clearly, in our auto-dominated societies, public transport has lost most of its old development-shaping role, if indeed it ever did shape central cities in the fashion so commonly believed. The evidence overwhelmingly supports the view that rapid transit was introduced long after core and central area densities had peaked and that these systems amplified rather than diminished the "flight to the suburbs." BART impacts in general were in keeping with the scale of the BART infrastructure costs to the investment already in place in the area.[12] We talk of "migration back to the central cities" and "regentrification," but the recent 1980 U.S. Census figures confirm the continued declining or negative growth rates of our cities, even our southern and western ones. Diffusive growth of our cities implies a slow continuing erosion of transit (and ridesharing) potentials.

Most planners would agree that there are density thresholds[13] that vaguely determine market viability for bus and rapid transit. We think they are in the range of 3,000 people per square mile for buses and 10,000 people per square mile for rapid transit. Others have suggested employment density criteria be added.[14] Changes in the number of people residing inside the above bus and rail density thresholds represent changes in the market potentials for these modes. Studies of the impact of UMTA transit expenditures for several U.S. cities show that after correction for the changes in transit market potentials, ridership trends correlate well with per capita investments by UMTA in the cities' transit systems.[15] Therefore, the urban form influences not only the overall level of transit usage, but within transit the relative usage of rail versus bus systems. The implication of our work is that trends in urban form will negatively impact rail transit to a greater degree than bus transit, and that there may well be some untapped bus market potential in small to medium sized cities deserving of attention.

The trends in urban form also have significant implications for transit operating subsidies. As early as 1970 we forecast[16] that the combination of evolving urban form and transit fare policies would lead to as much as a 26% per year growth rate in transit operating subsidy requirements. In 1975 legislation was passed authorizing Federal operating subsidies to urban transit operators. In 1977 we forecast[17] that the rapidly increasing subsidy requirement (30% per year actual) would create a basic instability in the mass transit industry, leading to service rationalization in the 1980s. That rationalization has already begun. The Federal government has announced its intent to phase out its support of operating subsidies. Fare policies and service levels are now being re-examined and changed. User charges will be used to recover a greater share of operating costs than results from current policies (40% to 50% of operating costs now come from farebox revenues). The increasing pressures on the industry and government will have important effects in shaping Federal programs. Internal management of transit operations will be an issue of growing concern. The role of Federal, State and local governments in this process will also be issues of growing concern. R&D will shift more from hardware systems development to "soft" knowledge base research and industry analysis.

In reality, the basic instability in the mass transit industry, arising in large part from the dynamics in urban form, has been present for decades.

The inability or unwillingness of local and State governments to control the situation is what prompted the Federal government to take a role in transit in the 1960s. In all fairness, it was acknowledged that post World War II Federal polices (in home mortgages, for example) helped create "urban sprawl" and enhanced dependence upon the automobile. Be that as it may, the effects of that same instability now confront the Federal program planners as a major strategic issue requiring careful thought.

Cutbacks in new starts and extensions of rapid transit, greater relative priorities for bus operations, a more conservative approach to the rate of development and deployment of "new systems" technologies are all consistent with the macroscopic trends in urban form. So too are shifts in R&D to efficiency improvements in conventional systems management and operations. To some degree, in the current national environment, these trends are inevitable as are the consequences of service cutbacks and system consolidation.

However, many of us intuitively feel that a better case can be made for mass transit. Some form of mass transit is employed in practically all medium and large cities in the world. Its existence in cities of medium and large scale, the growing dominance of rapid transit in dense areas of large cities,[18] all suggest that transit has some very significant properties we do not yet understand on a macroscopic urban scale. They are likely related to non-linear congestion effects that are probably important in the increasing diseconomies of scale of large cities. Many of us sense that these issues are also related to energy policy issues that are already clearly on the world agenda.

Energy

The initial response of the Federal government to the energy shortages created by the oil embargo of 1973 focused upon automobile use and subsequently on auto technology. Our studies[19] indicated that these were the areas of greatest conservation potential. Ridesharing had great conservation potential if it could be promoted and many programs were initiated to test the magnitude of effects that could be realized.

While it is certainly true that intense social emphasis on behavioral change in ridesharing may work significant conservations if accompanied by intelligent planning and systems development, planners should recognize that they are working against the tide of urban form trends. The same diffusive growth that erodes transit market potentials leads to a steady decline in carpool potential for constant behavioral parameters. We estimate this decline at between 1% and 3% per year.[20]

Another common perception is that modal shifts from auto to transit would promote energy conservation. Again, while it is true that fuel efficiency of bus or rapid transit may be superior to those of autos (of current design), massive shifts from auto to transit are required. These shifts are contrary to the trends discussed above and are incompatible with the auto dependent character of our cities.

The diffusive growth of cities and the related diffusion regionally that is reflected in city size distributions also has a primary impact upon per capita energy consumption requirements. In the intercity it means average freight trip lengths have been growing at about 1% per year for at least the last 30 years.[21] Intracity, it probably implies similar effects. (The Federal government does not have any significant research program in urban goods movement.)

Auto Ownership and Use

Clearly, the complementary side of the above stories is the story of auto ownership and use in U.S. cities. We have already stated the primary relationship relating to issues of urban form. The Federal policy concern is with industrial policy and the Federal role in supporting and regulating the auto industry. We are now seeing the ramifications of dependence upon automobiles (and trucks) in an era of emerging energy constraints and the industrial instabilities triggered by the decade-long process of product and process technology change necessary to make initial adjustments. It is probable that we have really just begun. Plans are on the boards for efficient urban autos, but we need to re-examine our basic assumptions about the market demand for autos, including the implicit ones of trends in urban form. Will the future trends in form resemble the past? Can we expect radical changes in urban form? If so, in what time frame?

Future Urban Form and Transportation Issue

Those of us interested in issues of transportation and urban form wonder what the real impact will be of population growth, and the future constraints of energy, natural resources, technology, and the economy. Will cities become more dense? Will communication replace transportation to increasing extents?[22] Will people increasingly desert the large cities or give up their mobility and settle for more neighborhood-oriented life styles?

Any complex system, the urban system included, exhibits hysteresis. It will not retrace its path exactly if the conditions leading up to its present state are reversed. Modelling the urban system is a major research challenge, and our present capabilities are primitive, albeit hopefully on the right track scientifically. For the last several years the focus of our work has been to try to forecast urban evolution in the presence of significant energy constraints. We have much of our work still before us. What is clear is that the time scale for change is long, much longer than implied by the current dialogue we often hear. Major buildings may take years to construct, as do large scale groups of small housing units. The skyline of a major area of a city takes perhaps two decades to emerge. But the coherent behavior of the whole urban area requires perhaps 70 or 80 years to experience fundamental change, or perhaps longer if the basic diffusive character is to be changed. Controlling forces relate to the maximum rate of capital reinvestment and the rate of loss of utility of existing infrastructure. We are not noted as a nation of planners. We are developers and redevelopers (i.e., marginal builders).

Accordingly, we expect to see continuations of past trends with rates influenced strongly by the changing constraints, but macroscopic trends remaining reasonably inertial. Persistent fundamental changes in energy supply or other basic variables would necessitate behavioral changes within the existing structure while the long term effects sort themselves out.

Conclusions

Transportation systems and urban form are intimately related. Their evolutions are necessarily closely tied together. In analyzing policy issues and (programmatic) implications, it must be understood that there are physical hierarchies of spatial scales and processes related to the spatial scales, with characteristic cycle times that are important in different ways to people of different position in the human social and economic hierarchies. Individual building and construction times are small scale examples. Neighborhoods and decade settlement times are intermediate scale examples. The city itself and a human lifetime are commensurate scales at the macro extreme. Furthermore, issues at one scale impact the other scales. The general urban area growth affects central density. Beltway construction may give rise to shopping center concentrations.

Federal policy issues and program evolution in transportation are strongly influenced by issues of urban form. Mass transit, transportation energy, and automobiles are the current focus of Federal concern. Federal involvement is directly traceable to the most macroscopic aspects of urban growth and competition. Subordinate levels of government must necessarily deal with what, to a Federal official, is a "fine structure" issue. The Federal official usually is content if "equity" considerations seem to be satisfied.

The current Federal policy directions in urban transportation are clearly consistent with long-standing trends in the evolution of urban form and the related transport behavior of urban residents. That behavior is in large part conditioned by competing technologies and their attendant costs given the urban form evolved to that point.

The long term implications of these trends are not particularly pleasant for advocates of mass transit, persons concerned with energy conservation, or consumers, workers, and businessmen concerned with a stable and increasingly productive industrial economic base. Since that includes us all, we have a common interest in developing a better understanding of the evolution of transportation and urban form and in those actions we can take to implement more effective policies on all levels.

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TRAVEL AND URBAN FORM:
EMPIRICAL RELATIONSHIPS AND POLICY IMPLICATIONS

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Abstract

This paper reviews a number of studies of the relationship between urban form and household travel behavior and presents some new empirical results concerning this relationship. Earlier work has provided evidence of a strong relationship between urban form and travel behavior. In particular, this work has suggested that influencing urban form through land use and transportation investment policies may be an effective way of reducing the demand for automobile travel. Certain types of urban form can be encouraged, it has been argued, which will have relatively low levels of automobile travel, energy consumption, and environmental pollution.

The results of a recent statistical analysis of travel data from eight metropolitan areas in the U.S. are used in this paper to explore the influence of urban form on levels of automobile travel. The analysis suggests that much of the association between urban form and travel behavior observed in earlier studies can be attributed to neighborhood household characteristics, automobile ownership, and transportation system characteristics such as automobile travel speeds and transit service levels. Policymakers should recognize that changes in urban form are not likely to produce significant reductions in levels of automobile travel unless they are accompanied by appropriate transportation system management measures and policies which bring about supportive household location decisions.

Introduction

The problems associated with urban travel have become a matter of considerable concern in the United States. Gasoline consumed in vehicular travel has contributed to an increasing dependence on foreign sources for petroleum, and the pollutants emitted by automobiles, buses, and trucks have been largely responsible for poor, and at times, hazardous air quality in many urban areas. The quality and level of ridership of many transit systems have declined greatly over the last three decades, resulting in alarming increases in the public expenditures needed for transit. Many auto drivers still encounter major traffic delays in their journeys to and from work--delays which sometimes vary greatly as a result of weather conditions, accidents, or periodic road reconstruction and maintenance.

The positions of public policymakers in relation to these problems have changed over time. Until fairly recently many officials saw their role as one of consistently providing more mobility for urban residents. Transportation policy was aimed at avoiding congestion, delay, and inconvenience through a regular program of expansion of the capacity of the transportation system. A number of factors have combined in recent years to alter this approach to transportation problems. The sharply rising financial, social, and environmental costs of accommodating increases in the demand for travel have caused many people to question the desirability of continuing this policy. Increasingly, policymakers have begun to look for ways to reduce the demand for mobility and bring about a more efficient pattern of travel.

Strategies to guide the growth and development of urban areas have been advocated as an important means of influencing travel demand, as reported, from a meeting in May, 1976 of European Ministers of Transport:

> The residential districts which have emerged on the edge of urban areas are mostly suburban in character. These districts are not very compact, which means that providing good public transport is very difficult and very costly... The aim should be perhaps to concentrate residential areas and work places more closely together, if only to bring down public and private transport infrastructure costs...
>
> Furthermore, better land use planning (functional integration) may lead to dispersal of traffic in several directions in cases where much of the existing peak hour traffic is confined to one direction only. Walking and cycling may then become acceptable alternatives and the urban environment thus further improved.[1]

A particularly strong recommendation for land use policy as a means of tackling the "urban transportation problem" has been made by the New York Regional Plan Association:

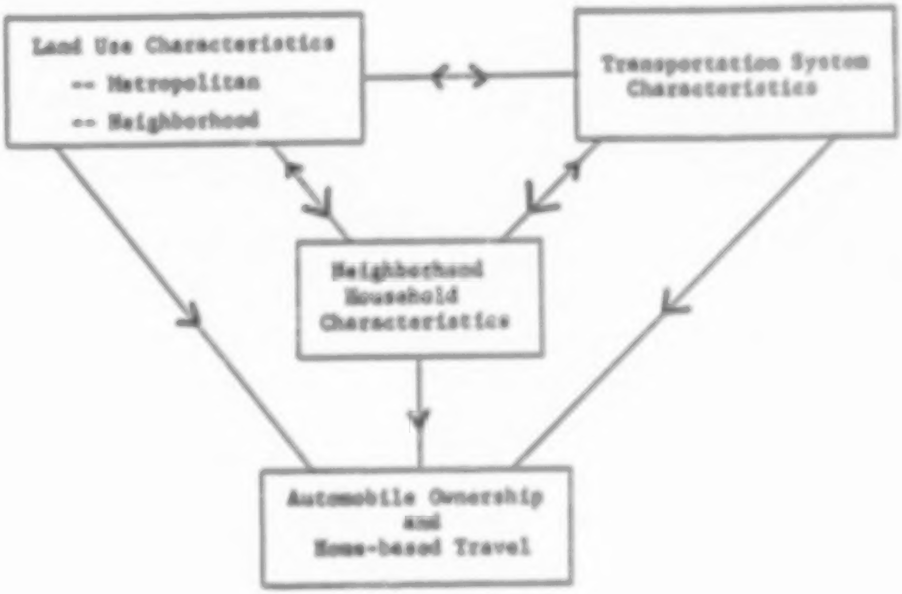
> The solution to the urban transportation problem will lie not primarily in devising new forms of transit but in bringing about radical changes in land use policy. In essence, the goal would be to reverse the present trend of business, industry, and services to the fringe of cities. Additionally, the density of urban residential neighborhoods should be increased, especially around existing or potential transit stops.[2]

In many cases prescription of this kind are based upon observations that certain land use patterns are associated with preferred forms of travel behavior. This paper reviews a number of studies which suggest that a strong relationship exists between land use characteristics and descriptors of urban travel such as average vehicular trip length, trip duration, trip frequency, mode choice, and overall vehicle miles of travel. These studies give only limited guidance, however, on the extent to which changes in land use characteristics would actually bring about changes in travel behavior. In general, current understanding of the relationships which link land use characteristics to travel behavior does not permit confident statements about the potential of influencing travel patterns through land use policies.

This paper explores certain aspects of the relationship between land use characteristics and travel behavior using empirical evidence from U.S. cities. The analysis scheme, shown in Figure 1, proceeds from the point of view of a policymaker contemplating the likely effects of changes in land use characteristics on the travel generated by neighborhoods in a metropolitan area. The first set of relationships in Figure 1 links land use characteristics to transportation system characteristics, such as highway infrastructure and the availability of public transportation services. The second set links the characteristics of the households which choose to locate in a neighborhood to land use and transportation system characteristics, and the third set links neighborhood automobile ownership and home-based travel to land use, transportation, and household characteristics.

FIGURE 1

STRUCTURE OF EMPIRICAL ANALYSIS OF
TRAVEL GENERATED BY NEIGHBORHOODS


Land Use Characteristics
-- Metropolitan
-- Neighborhood
Transportation System Characteristics
Neighborhood Household Characteristics
Automobile Ownership and Home-based Travel

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The first set of relationships between land use and transportation system characteristics is undoubtedly very complex. Public decisions to expand transportation infrastructure influence decisions by developers on the location and characteristics of housing, shopping, and industrial developments. Travel generated by these developments in turn influences new decisions on transportation infrastructure. This paper does not attempt to unravel these complex cause and effect relationships, but rather identifies certain empirical relationships in U.S. cities between land use and transportation system characteristics. Because these empirical relationships are the outcome of a series of interrelated decisions made over a period of years, policymakers cannot assume that new land use initiatives will automatically be accompanied by the transportation system characteristics implied by these existing relationships.

The second set of relationships illustrated in Figure 1 deals with the interaction between land use and transportation system characteristics on the one hand and neighborhood household characteristics on the other. Households make location decisions based in large part upon the land use and transportation characteristics of the neighborhoods available to them in a metropolitan area. When they decide to locate, they consider the housing and local features of alternative neighborhoods as well as their options for automobile ownership and travel. Large households may tend to locate in low density neighborhoods with single family homes and plan on considerable automobile travel, for example, while households which, because of economic or other reasons prefer not to rely on the private automobile for their travel, may locate in neighborhoods with good public transportation service. These household location decisions may in turn influence decisions about new land use development and transportation system changes, so that, as with the first set of relationships discussed above, questions of cause and effect are quite complex. The empirical analysis reported here does not address this second set of relationships directly, and this subject is identified as one for which new research and understanding are needed.

The third set of relationships shown in Figure 1 describes automobile ownership and travel behavior resulting from the interacting decisions of households, firms, and public bodies discussed above and is the focus of most of the analysis presented in the paper. The analysis develops empirical relationships expressing automobile ownership and travel behavior as functions of household, land use, and transportation system characteristics. It is emphasized, however, that when policymakers set out to influence travel patterns through land use changes, they must consider the more complex interactions denoted at the top of Figure 1. Their problem is essentially to attract the appropriate kinds of population as well as to create the appropriate transport conditions for the type and amount of travel desired.

Hypotheses From Transportation Planning Studies

Much of the research to date on the relationship between land use and urban travel has been conducted in conjunction with the application of methodology for long range urban transportation planning. This methodology is concerned with forecasting vehicular trips by origin, destination, mode, route, and time of day over a forecast period of up to twenty years. The results of these forecasts are used in the design and evaluation of alternative transportation system plans, which might include, for example, considerable new highway construction, extension of a rapid rail system, or substantial changes in fixed route bus services.

Although the standard methodology for transportation planning assumes away several potentially important relationships between travel, transportation supply and land use, the traffic zone data collected as a basis for forecasting provide a means of analyzing some of these relationships directly. A number of studies have used these and other data to relate average household trip length, trip duration, trip frequency, modal choice, and overall vehicle miles of travel (VMT) to various descriptors of urban land use. The results of these studies are reviewed briefly in the following sections, based on a more detailed review reported in Neels (et al. 1977). Several tentative relationships suggested by the studies are then summarized for comparison with the new empirical results developed later in the paper.

Trip Length and Trip Duration

Alan Voorhees and Associates (1968) used data from 34 metropolitan areas to analyze the relationships between vehicular trip length, trip duration, and some simple descriptors of land use in the areas. They concluded that the average length of trips of all types increased with metropolitan population size but was not influenced by the average density of an urban area. Further, they found that trip length for work and social-recreation trips was very sensitive to speed: a 10% increase in average speed was estimated to lead to a 14% increase in average trip length. The fact that average traffic speeds generally increase as one moves away from the urban center to less dense areas[3] suggests an important and verifiable relationship: work trip length tends to increase with distance from the central city. The Voorhees study also concluded that the average work trip duration for a metropolitan area was "almost a linear function of the average distance of (the residences of) workers from the CBD." To the extent that distance to the central business district (CBD) can be interpreted as a proxy for the distance separating household locations from jobs, the Voorhees study suggests that both trip length and trip duration increase with the separation between residences and jobs. The importance of metropolitan area population in explaining average trip length was confirmed by empirical work done as part of a study of the impacts of a proposed beltway around the city of Richmond, Virginia.[4]

The principal factors which emerge as being closely related to trip length and duration are population size and the average separation between activities. On the basis of existing evidence, however, it is difficult to determine how they are related or even whether one merely serves as a surrogate for the other. Density, at either the neighborhood or the metropolitan level, appears to be only very weakly related to trip length.

Trip Frequency

Studies by Wilbur Smith and Associates (1968) and Deutschman and Jaschick (1968) concluded that within an individual urban area the number of vehicle trips per household is inversely related to local density. The fact that fewer vehicle trips are made by people living in high density neighborhoods may be interpreted in one or both of two ways. One possible explanation is that physical proximity to destination points allows households living in high density neighborhoods to substitute unrecorded and convenient walking and bicycle trips for vehicle trips. Alternatively, it can be argued that the congestion of high density neighborhoods reduces average auto trip speed, thereby discouraging automobile trips. To the time delays caused by congestion must be added the cost and difficulty of finding parking space.

Various other studies have indicated that walk trips are an important element of urban travel, whose frequency increases rapidly with density levels. A survey of non-work trips by all modes in the city of Buffalo, New York, found that total non-work trips in high density neighborhoods could be 25 to 35 % higher than in average density neighborhoods.[5] The incremental trips almost always were by bus or walking. Even among households with constant access to autos, more than one-fourth of all non-work trips in high density neighborhoods were made on foot.

However, many characteristics of the household itself enter into trip generation rates. Data from a nationwide survey analyzed by Stowers and Kanwit (1965) at the University of Michigan suggest that land use characteristics may have relatively little direct impact on household vehicle trip frequencies in comparison with household characteristics. According to this study, family size and auto ownership exert the most powerful influence on trip rates. Family size, auto ownership and household income tend to be negatively related to density. Though a strong negative relationship between neighborhood density and vehicle trip rates is found, the partial contribution of density alone, after control for other variables, may be small.

Traditional trip generation studies often neglect trips that do not originate or end in the home. But studies have found that as many as 50 % of all travel destinations in some cities are visited during multi-destination trips,[6] sometimes called "tours" or "journeys." This suggests that in studies of home-based travel alone the total number of trips made by suburban residents who rely heavily on the automobile for transportation may be underestimated relative to total trips by residents of other locations.

Vehicle Mode Choice

The same factors that are associated with walking trips also tend to be associated with mass transit: the share of total trips made by transit increases with neighborhood density. The study by Wilbur Smith and Associates (1968) suggests that in the most densely populated parts of Philadelphia, Pennsylvania, and Boston, Massachusetts, more trips are actually made by transit than by auto drivers. For all of the cities studied, the percentage of vehicle trips made by transit increases steadily with neighborhood density. The proportion of auto driver trips, on the other hand, remains relatively steady across most density levels, declining rapidly only above density levels of 50 persons per residential acre.

In comparisons between cities, it appears that while the simple correlation between overall urban density and transit usage is high, density is not the main explanatory factor for transit usage. In an econometric analysis of National Transportation Study data, Peat, Marwick, Mitchell and Company (1975) tested a number of demand functions in an attempt to estimate per capita passenger miles for both bus and rail transit. The authors concluded that "...for both bus and rail systems, the explanatory variables of average square miles per capita (the inverse of average population density), price, and headway were not sufficient to explain very much of the variation among urbanized areas in demands for transit services." The report suggests that socioeconomic characteristics of the residents, not included in the analysis, may explain more of the observed variation in modal split.

Vehicle Miles of Travel (VMT)

The relationship suggested above between land use and trip length, duration, frequency, and modal choice can be synthesized to give some indication of how VMT might vary with land use. Trip length and duration tend to increase as metropolitan area population increases. Trip frequency tends to decrease as neighborhood density increases, and the proportion of vehicular trips by transit tends to increase as neighborhood and employment densities increase. Consequently, overall VMT per household might be expected to decrease as neighborhood and job densities increase and as total population decreases.

The only other studies to examine VMT per household have been carried closely out as part of the evaluation of new town designs. Part of the rationale for new communities has been the possibility of reducing travel by the planned juxtaposition of complementary land uses. Evaluations of new communities in the United States, however, indicate that the desired travel savings have yet to be realized. A comparison of travel behavior in fifteen new communities with fifteen unplanned control suburbs showed no discernible reductions in VMT from planned design, except in the category of recreational trips.[7]

Summary

Research to date suggests the following relationships between household travel behavior and descriptors of urban land use.

- The length and duration of vehicular trips appears to increase with metropolitan area population and with the separation between residence and job locations. No study examined both factors, and so it is impossible to tell whether or to what extent they operate independently. There has also been disagreement on how to measure the residence-job separation.

- The frequency of home-based vehicular trips tends to decrease as neighborhood density increases, while the frequency of walking trips tends to increase. Much of this variation might be reduced, however, if the effect of household characteristics were taken into account. The inclusion of trips beginning and ending away from the home might modify these relationships, though the direction of change is not clear.

- The overall number of vehicle miles of travel per household tends to decrease as neighborhood and employment densities increase and as either the separation between residence and job locations or the population of the area decreases.

On the whole, these studies have identified a number of strong relationships between travel behavior and certain land use characteristics. The nature of these relationships, however, is not clear. The power of the neighborhood density variable, for example, in explaining the frequency of vehicular travel and the proportion of travel by transit is weakened considerably when variables such as family size, family income, and automobile ownership are introduced into the equation. It is likely that the same holds true for other facets of travel behavior. The direct relationship between land use characteristics and travel behavior is thus obscured by the existence of indirect links through intermediate variables.

Empirical Analysis of Eight U.S. Cities

The previous section suggested a number of relationships between travel behavior and the pattern of land use. The nature of these relationships remains unclear, however, because of the difficulty of separating the effects of land use characteristics like neighborhood density from the host of other important factors which tend to vary in similar ways. It is a well known fact that auto travel speeds in high density areas tend to be lower than in low density areas, and high density areas usually enjoy better transit service. High and low density areas may often differ consistently in their general proximity to employment and in average family size. All these factors can be expected to influence travel behavior. Thus, even if high and low density areas are observed to exhibit quite different travel characteristics it may be difficult to determine to what extent density alone and not some combination of these other forces is the cause.

The analysis reported below attempts to clarify some of these issues by expanding the scope of previous work, both in terms of the travel measures examined and the explanatory variables which are investigated. An attempt was made to account explicitly for the most important determinants of travel behavior in order to clarify the role of land use characteristics. Information was pooled from a number of different metropolitan areas to broaden the range of phenomena included in the data set and make it possible to examine the effects of metropolitan level land use factors as a residual influence after controlling for neighborhood variables.

The data set used in the analysis consists of a pooled neighborhood sample drawn from selected metropolitan areas where home interview travel surveys were conducted during the late 1960s and early 1970s.[8] This period was chosen so that the transportation variables could be combined with socioeconomic and other information drawn from the 1970 census. The urban areas included in the sample and the sampling characteristics of the original home interviews are shown in Table 1.

TABLE 1

HOUSEHOLD INTERVIEW SURVEYS
FOR LOCAL TRANSPORTATION ANALYSIS

Metropolitan Area	Year of Survey	Sample Size (Households)	Percent of Population in Sample
Dayton	1968	8,000	5.0
Denver	1971	16,000	3.0
Fresno	1971	7,200	6.7
Los Angeles	1967	33,000	1.0
Omaha	1966	2,240	1.0
Pittsburgh	1967	29,971	4.0
Washington	1968	30,000	4.0
Youngstown	1967	10,015	6.2

Cross-sectional analysis was conducted at the level of the neighborhood which is made up of two to four local traffic zones. The basic sample for which results are reported contains 234 individual "neighborhoods," drawn from eight metropolitan areas.[9] Stratified sampling procedures were used to ensure a wide scatter of traffic zones with respect to (1) distance from the central business district, (2) average income level, and (3) density. Neighborhoods were randomly selected from the different stratification categories.

A great deal of evidence exists which suggests that the nature of travel demand depends strongly upon the characteristics of the household whose members are doing the traveling. It is also true that household characteristics influence locational choices in important ways. Thus, to explain travel behavior adequately and to separate the effects of land use characteristics on travel from their influence on locational behavior it was necessary to incorporate measures of these household characteristics into the analysis. On the basis of previous work stressing their importance, household size and income were chosen as the primary variables of interest. The racial composition of the neighborhood was also included as a possible secondary factor influencing demand. Values for these variables were obtained from the U.S. Census. Adjustments were made to the income and population figures to take into account changes which had occurred between the time of the travel survey and 1970.

The pooling of data from different metropolitan areas with widely differing degrees of employment decentralization argued strongly against the use of distance to the CBD as a measure of job-residence separation. It was expected that the varying levels and concentrations of employment in the eight CBDs in the sample would greatly distort the results of such a use of the distance measure. Thus, residential density was the principal land use variable. However, the distance of the neighborhood to the CBD was included in several simple descriptive equations examining variations in transport supply.

Two measures characterizing the transportation system were incorporated in the study. Transit availability was measured from transit route maps obtained from the various metropolitan areas. The actual variable used to characterize transit availability was the proportion of the neighborhood within a quarter of a mile of a transit line. Using survey information as inputs, an average auto driver trip speed was obtained as an output of the local traffic network models.

Auto ownership data was obtained from the census and from information collected during the home interview surveys. Information on trip frequency, mode choice, and destination was generated directly from the local household surveys, with individual responses aggregated to traffic zone and then to neighborhood averages. The data on travel times and distances were derived by combining survey data on destination choices with interzonal times and distances derived from the network models described above.

The interest in this study lay in the effect of land use on particular travel decisions as well as in the cumulative effect, through the whole sequence of decisions, on the total volume of travel by residents of a neighborhood. This necessitated the development of a set of equations describing interrelated components of the decisionmaking process in such a way as to allow for measurement of these indirect effects.

Automobile ownership has been shown in previous studies to be an important factor in household travel decisions, and was estimated in this analysis as a function of land use, household and transportation system characteristics. The set of travel choices was then assumed to be structured as follows. First, residents of a neighborhood choose an average trip length. This corresponds to the definition of an activity field within which people conduct most of their daily business. If a wide diversity of activities are located close to the neighborhood, this field may be relatively small. If average speeds are high, so that the time per unit of distance is small, the field will be correspondingly larger. Finally, certain types of households may have preferences for a larger or smaller than average field. Trip duration is computed as the ratio of trip distance and trip speed. Vehicle trip frequency is then expressed as a function of trip duration, household, land use, and transportation system characteristics and automobile ownership. Mode choice is computed as a function of household, land use, and transportation system characteristics and automobile ownership. Separate equations are developed for transit use and work auto occupancy. Finally, auto vehicle miles of travel are computed using the results on trip length, trip frequency, transit use, and auto occupancy.

Empirical Results

Automobile Ownership

The results obtained illustrated the strong association, at the neighborhood level, between public transit availability and private automobile ownership.[10] High density neighborhoods and neighborhoods close to the urban center, other things equal, tend to enjoy better transit service. Auto ownership levels are high when densities are low. But even after control for land use characteristics, automobile ownership is negatively related to the availability of transit service. Auto availability was, of course, highly sensitive to neighborhood income levels, and to household size. A significantly lower level of car ownership is found among black households. This result appears throughout the analysis. Black families, even after control for household income and location, own fewer autos and rely far more heavily on mass transportation for urban travel than white families.

Table 2 shows the relationship between travel behavior and household characteristics, automobile ownership, land use characteristics, and transportation system characteristics. Elasticities for home-based auto vehicle miles of travel were derived using the observed average auto occupancy for all the neighborhoods in the sample and the formula:

$$\text{VMT} = \frac{\text{(Vehicle trips)} \times \text{(1-Transit share)} \times \text{(Trip length)}}{\text{(Average auto occupancy)}}$$

Trip Length

Average speed had extremely powerful effects on trip length. The elasticity for speed, in fact, was greater than one, suggesting that highway improvements will tend to increase the amount of travel and not simply make it faster. In comparison, the relationship between trip length and density and income was much weaker.

TABLE 2

DERIVED ELASTICITIES OF TRAVEL BEHAVIOR

	Trip Length	Trip Duration	Trip Frequency	Transit Use	VMT
Household Characteristics					
Income	+ .1	+ .1	+ .2	- .6	+ .3
Household Size			+ .8	- .4	+ .8
Race			- .03	+ .04	- .03
Automobile Ownership			+ .6	- .7	+ .6
Neighborhood Characteristics					
Neighborhood Density	- .1	- .03	- .2	+ .5	- .2
Distance to CBD	+ .1	+ .01	- .01	- .6	+ .1
Transport System Characteristics					
Transit Availability			+ .03	+ .3	+ .02
Speed	+1.1	+ .1	- .01	-1.1	+1.1

Metropolitan "dummy" variables explained a significant amount of the variation in trip length. In fact, there appeared to be more variation between metropolitan areas than within them. The metropolitan level effects here were quite powerful. The work reported in the literature review suggested that trip length should be positively related to the population of the metropolitan area. This assertion was borne out weakly by the results of this analysis.

Trip Frequency

The most important explanatory variable for trip frequency was average auto ownership, followed at some distance by average household size. These results correspond exactly to those of the Stowers and Kanwit study reported earlier.[11] Even after controlling for these two factors, however, density still seemed to exert a strong negative influence on the trip generation rate, perhaps because of an increasing reliance on walk trips as densities become higher. The inconvenience of parking and operating a car in high density areas would also tend to reduce auto vehicle trip making. Transit trip making should be easier in high density areas, but apparently this effect is not sufficient to offset the reduction in auto use.

Transit Use

Auto ownership and the racial composition of the neighborhood played an important role in determining transit use. When automobiles are scarce or unavailable, people are forced either to use transit or to seek rides with other drivers. The racial variable remained significant even after location, density, income, and auto ownership are taken into account. This corresponds to the result derived earlier in connection with auto ownership. Blacks consistently seem to rely less on cars.

The transit use results appear to reaffirm the importance both of density and distance to the CBD as determinants of transit ridership. The metropolitan "dummy" variables also appeared as important explanatory factors The magnitudes of the coefficients varied substantially from one area to another, and in most cases they appeared to be highly significant. Thus, it appears that metropolitan level factors are important in explaining this aspect of travel behavior.

Vehicle Miles of Travel (VMT)

Home-based auto VMT, computed using the formula presented earlier, was determined primarily by the most important explanatory variables for its component variables. Average speed and automobile ownership had the strongest influence, followed by average household size. The influence of the neighborhood land variables and the metropolitan "dummy" variables was much weaker.

Conclusions and Research Needs

Studies of transportation and land use have suggested that certain descriptors of urban land use are strongly associated with household travel behavior. Increasing residential and employment densities tend to be correlated with reductions in vehicular trips and with increased transit usage. Decreasing metropolitan population and separation between neighborhood and job locations tend to be associated with reductions in vehicle trip length and duration. It is not altogether clear from the studies, however, to what extent these relationships should be attributed to household variables, which also influence travel behavior, such as size and income to automobile ownership, or to transportation system variables such as transit availability and traffic speeds. If the effect of these other variables were included, how important would land use variables be in explaining the remaining variation in travel behavior?

The neighborhood analysis of household travel reported in the previous section concluded that much of the association between land use characteristics and travel behavior is due to the influence of a variety of related factors. The transportation system, measured in terms of transit availability and auto speed, and a number of important household characteristics are strongly related to residential densities. Once these influences were taken into account, the associations between density and travel behavior remained statistically significant, but were greatly weakened.

Neighborhood land use descriptors (distance to the CBD and neighborhood density) were strongly associated with the transportation system characteristics. Transit availability increased and auto speeds decreased as neighborhoods became more dense and closer to the CBD. Weaker direct relationships were found between neighborhood land use descriptors and travel behavior. As neighborhood density increased, fewer total vehicle trips were made, a higher proportion of these trips were made by transit, and auto driver trip lengths became shorter. Transit use also increased as distance to the CBD decreased.

Land use descriptors at the metropolitan level displayed some strong associations with the transportation system characteristics. Though no pattern of association could be identified for transit availability, auto speeds were observed to increase as the concentration of employment in the CBD decreased. Because of the limitations of the empirical analysis, statements about the direct relationship between metropolitan land use descriptors and travel behavior must be very tentative. Subject to this qualification, however, they did seem to play a potentially important role. Even after accounting for transportation system characteristics, house characteristics, and neighborhood land use characteristics, important differences in travel behavior were observed among metropolitan areas. This was particularly true in the cases of auto trip length and transit use. In conformity with the results of earlier work, trip length did seem to be positively related to metropolitan populations. For transit use, as for transit availability, no particular pattern was observable.

These metropolitan level results cannot be considered conclusive. The limited number of areas in the sample and the difficulty of pooling data from diverse sources make generalizations hazardous. The most pressing requirement for further work in this area seems to be an expansion of the number of metropolitan areas investigated. This would make it possible to look into the impacts of different metropolitan characteristics or explore possible interactions between metropolitan and neighborhood factors. Until this is done, the present results must be considered as little more than suggestive.

In summary, the direct influences of neighborhood and metropolitan land use characteristics on travel behavior were found to be significant but not particularly well-defined or strong. The results do not suggest, therefore, that land use policies alone are likely to be an effective tool for reducing VMT or otherwise influencing travel behavior. To be confident of arriving at a desired kind of neighborhood travel behavior, policymakers must also create the right kinds of transportation system characteristics, and ensure that certain kinds of people and activities are attracted to the neighborhoods of interest. The results identify controlling automobile speeds as perhaps the most important element of the overall strategy. Whether such a coordinated approach to influencing travel behavior can be formulated and implemented in U.S. cities is a question for contemplation by researchers and policymakers alike.

Acknowledgement

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"An Empirical Investigation of the Effects of Land Use on Urban Travel," by Kevin Neels, Melvyn Cheslow, Ronald Kirby, and George Peterson; Urban Institute Working Paper 5049-17, 83pp., 1977

NOTES

1. Council of Ministers, Report on Problems Concerning City Traffic Peaks (European Conference of Ministers of Transport, 1976).
2. Regional Plan Association, "Where Transit Works: Urban Densities for Public Transportation," Regional Plan News, No. 99 (New York: Regional Plan Association, 1976).
3. Highway Research Board, Highway Capacity Manual, Special Report 87 (Washington, D.C.: Highway Research Board, 1965).
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5. R.E. Paaswell and J. Berechman, "The Urban Disadvantaged and the Search for Locationed Opportunity," Traffic Quarterly 30 (1976): 85-100.
6. G.C. Hemmens, The Structure of Urban Activity Linkages (Chapel Hill: Center for Urban and Regional Studies, University of North Carolina, 1966).
7. R. Burby, S. Weiss, and R. Zehner, A National Evaluation of Community Services and the Quality of Life in American New Towns (Chapel Hill: Center for Urban and Regional Studies, University of North Carolina, 1974).
8. Most urban areas carried out surveys of this type during the late 1950s and first part of the 1960s, using Federal funds. Far fewer areas have conducted such surveys recently. Those that have, have usually done so as part of the planning for new transit or highway systems.
9. Missing data necessitated the exclusion of selected neighborhoods and in some cases whole metropolitan areas from certain regressions. Because of the limited size of the sample, an attempt was made to include the maximum number of data points in each part of the analysis. Thus, the actual sample used for the regressions varies slightly from one equation to another.
10. The equations were generally estimated with log-linear functions. For transit usage, which must lie between 0 and 100%, "S"-shaped logistic functions were used.
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HUMAN ENERGY EXPENDITURE IN DIFFERENT MODES: IMPLICATIONS FOR TOWN PLANNING

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Abstract

The disproportionally strong resistance to walking distances and the decision to use the private car as a means of transport may be explained by taking into account the energy expenditure involved in walking or using various transportation systems. Raising the travelling speed of public transport, as well as imposing limits on the parking space available at the destination, unfortunately, are not adequate instruments for making a reasonable choice of some means of transport if "equality of opportunity" is not provided at the point of origin, i.e., in residential areas. This equality can be brought about only if the subjectively assessed travel-time components, i.e., the walking distances to public means of transport, do not become longer than those to the parked vehicle. This would lead to a type of town with limited-traffic pedestrian catchment areas in residential districts and central car parks or garages near the stops of public transport. The results of this study are in line with empirical efforts aimed at reducing the traffic in most European towns.

Introduction: The Problem

Classical urban planners and road builders make assumptions about human behavior which have not been tested for the very simple reason that people working in these fields have technical backgrounds. There are density model data pertaining to transit stops indicating that whereas a value of 300 meters distance between transit stops is acceptable in the town center, in suburbs as much as 800 meters is acceptable. However, these data do not stand up to critical examination. The density model data would suggest that if the people in the center city were to change places with the people in suburbs, behavior (and attitudes) would change correspondingly. This suggestion is in error.

The primary technical planning error is based on the assumption that objectively measureable data can be processed objectively by human beings. According to this assumption, time and distance are accurately experienced by human beings in the same way as they are measured by a watch or measuring tape. This is very doubtful. Not even organisms as simple as insects "work" in this way, as Frisch showed in his works on the behavior of bees.[1]

To bees, distances are interpreted as different degrees of resistance. For example, Frisch demonstrated that bees communicate walking distances of 3-4 meters as equivalent to flying distances of 60-80 meters. The assumption is made that if people in the suburbs were exchanged for people in the center city, behavior would change as place of residence changes. This assumption is in error.

This information, which has been available for some 50 years, would seem to indicate that even more complicated organisms such as human beings perceive quantities that appear easy to measure physically--such as time or distance--not in a physical but in a subjective way. If so, ignoring this information may give rise to serious mistakes in our planning.

In 1972, for example, it was shown in Hamburg[2] that with a linear increase in walking distances the resistance to such distances increases disproportionately. Another study done in Berlin[3] revealed that the same transportation system is perceived (subjectively) to be slower by people who have to walk long distances than by people who live in close proximity to a stop. Both studies suggest the existence of certain subjective transformation mechanisms. (Figure 1)

Man as a Measuring Device in the Traffic System

If the physical effort involved in two types of movement:

1. walking[4] and
2. driving[5]

is compared, the pulse frequency represented by the heart rate ratio (HRR), may be used as a first approximation of the physical achievement. For a walker this ratio is about 1.5 and for a driver 1.1--1.2.

If this measure is used to calculate the difference in energy consumption in the two different types of movement, a quadratic increase in resistance over time can be seen. (Figure 2)

This quadratic equation approximates closely the results of earlier empirical studies. This means that there is a quadratic increase, over time, in resistance to walking distances as compared with driving.

If they are experienced subconsciously, time delays which lead to a deviation from the expected expenditure of time also are subjectively experienced disproportionately.[6] With increasing disturbance this subconscious overestimation of time loss penetrates into consciousness and from then on times are measured relatively accurately. (Figure 3)

Presumably these relationships do not show an absolute distributional function (for all areas) but depend on various conditions: the rider's mental state and the overall character of the transportation system (calibration by system). This approach only shows that, in measuring time and distance, man does not feel and react in accordance with physical laws solely, but also transforms objectively measurable quantities into subjective modes of behavior.

Influence on the Modal Split

Considering the non-linear transformation of time and distance, the foregoing discussion suggests that urban density models which are public transport preference oriented have to be questioned in their present form.

Thus every road user subjectively compares the various traffic system available according to:

a. the objectively measurable time Tj_k, where k denotes the traffic system, and

b. a certain subjective time assessment factor derived from the total of the individual travel time components in the respective system.

If public transport and individual traffic are taken as options and differentiated by the subjective time components, the results are:

$$y = \frac{F_{ijp}}{F_{iji}} = \left\{ k \left[\frac{T_{iji} \cdot f_i}{T_{ijp} \cdot f_p} \right]^{\alpha} \right\}_P$$

y = modal split

T_{iji} = travel time in individual traffic

T_{ijp} = travel time in public transport

where

$f_i = f\,(t_1')$

$f_p = f\,(t_2')$ are subjective assessment factors

$$\frac{\partial y}{\partial t_1'} = k \left[\frac{T_{iji}}{T_{ijp}}\right]^{\alpha} \left[\frac{f_i\,(t_1')^{\alpha-1}}{f_p\,(t_2')^{\alpha}} \cdot \frac{\partial f_i\,(t_1')}{\partial t_1'}\right]$$

$$= k \left[\frac{T_{iji}}{T_{ijp}}\right]^{\alpha} \left[\frac{f_i\,(t_1')}{f_p\,(t_2')}\right|^{\alpha-1} \cdot \frac{1}{f_p\,(t_2')} \cdot \frac{f_i\,(t_1')}{t_1'}$$

change of modal split according to subjective components of individual traffic

$$\frac{\partial y}{\partial t_2'} = k \left[\frac{T_{iji}}{T_{ijp}}\right]^{\alpha} \left[\frac{f_i\,(t_1')^{\alpha}}{f_p\,(t_2')^{\alpha+1}} \cdot \frac{\partial f_p\,(t_2')}{\partial t_2'}\right]$$

$$= k \left[\frac{T_{iji}}{T_{ijp}}\right]^{\alpha} \left[\frac{f_i\,(t_1')}{f_p\,(t_2')}\right]^{\alpha-1} \cdot \frac{1}{f_p\,(t_2')} \cdot \boxed{\frac{f_i\,(t_1')}{f_p\,(t_2')}} \cdot \frac{\partial f_p\,(t_2')}{\partial t_2'}$$

change of modal split according to subjective components of public transport

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It can be seen from these formulae that the sensitivity of the modal split to public transport t_2 is proportional to the sensitivity to individual traffic multiplied by a factor constituting the ratio of subjectively assessed travel times in individual traffic and in public transport. With today's urban pattern this factor will always be smaller than 1.

Therefore, an improvement of the modal split through the acceleration of public transport will be connected with this damping factor. For practical examples of equal travel time but with different compositions of the individual time components, see Figures 4-6 which show the effects on modal splits for 4 different examples.

This makes it clear why the public transport acceleration measures carried out in most European countries and aimed at increasing travelling speed have had little effect on ridership rates. Restrictive measures, such as parking fees and limited parking zones at destination points, also show relatively little effect because equality of opportunity for various means of transport gets lost from the start. Therefore, it is important to have this equality of opportunity at the point of departure and not at the destination point. A key element is the walking distance to the respective means of transport.

Conclusions for New Urban Models

Due to advertising, high convenience and safer operation, man shows a strong propensity towards individual car use, and this fact has serious unfavorable consequences in conurbations. The present organization of different traffic systems and activities in the environment does not allow equality of opportunity between individual and public transport (considering man's subjective mechanisms of transformation). The disproportionate resistance to walking distances to public transport stops cannot be compensated for by accelerating public transport. In order to readjust the balance of the "organism of conurbations," adequate resistance to individual traffic has to be built into the system, that is, equal walking distance (energy consumption) to the parking space. In practice, this means that collective parking garages will have to be constructed near public transport stops, even in residential areas; individual traffic in the form of stationary vehicles will have to be eliminated from residential areas, and demands for low-traffic zones and areas of communication will have to be considered. For certain purposes (but not for parking), these zones may of course be used by individual traffic. With this type of town both groups of road users are forced to use common ways, and this would help to prevent the isolation which exists today and which is aggravated by the traffic system. (Figure 7)

The need for these changes results from observing actual human behavior in which physical quantities such as time and distance are transformed subjectively in different ways. Since subjective resistance to certain journeys is dominated by the walking distance, urban planners who focus on people's needs will have to consider, more carefully than before the requirements of pedestrian traffic. In land-use planning, quantitative proof of equal accessibility by public and private means of transport will have to be furnished in order to find locations for all activities. In practice, this will be tantamount to shifting parking spaces away from apartments and, as a result, creating areas free from individual traffic. This applies to suburban areas, central areas, and to the region as a whole.

These measures will not only lead to an improvement in the modal split but also to a more critical attitude on the part of public-transport users.

Disregarding the subjective mechanisms of transformation, which can be explained from ergonomic studies, the planning of towns and traffic systems will lead, in spite of formal planning rules, to a further destruction of the environment and to unresolved traffic problems.

Planning for human beings is possible only if their behavioral mechanisms, within the given technological system, are actually known. The connections derived in this paper constitute a first step towards a better understanding of the phenomena described herein, and they call for a complete departure from the existing patterns, encouraged by contemporary and urban models.

FIGURE 1

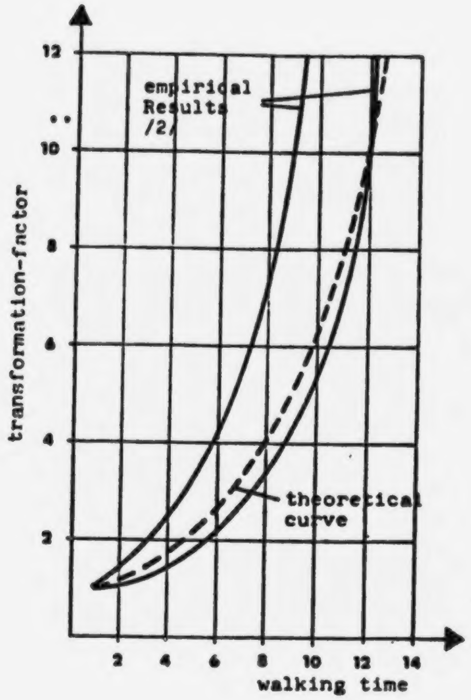
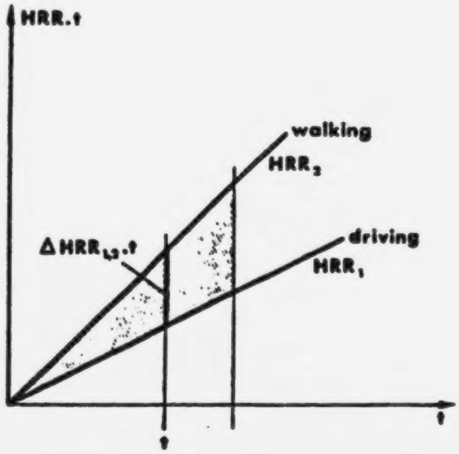


FIGURE 2


HRR.t
walking
HRR_2
driving
HRR_1
$\Delta HRR_{1,2}.t$
t
t

$$E = \int_0^t \Delta HRR(t) \, . \, t \, dt$$

and if ΔHRR is constant this gives

$$E = C\frac{\Delta HRR . t^2}{2} = W$$

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FIGURE 3

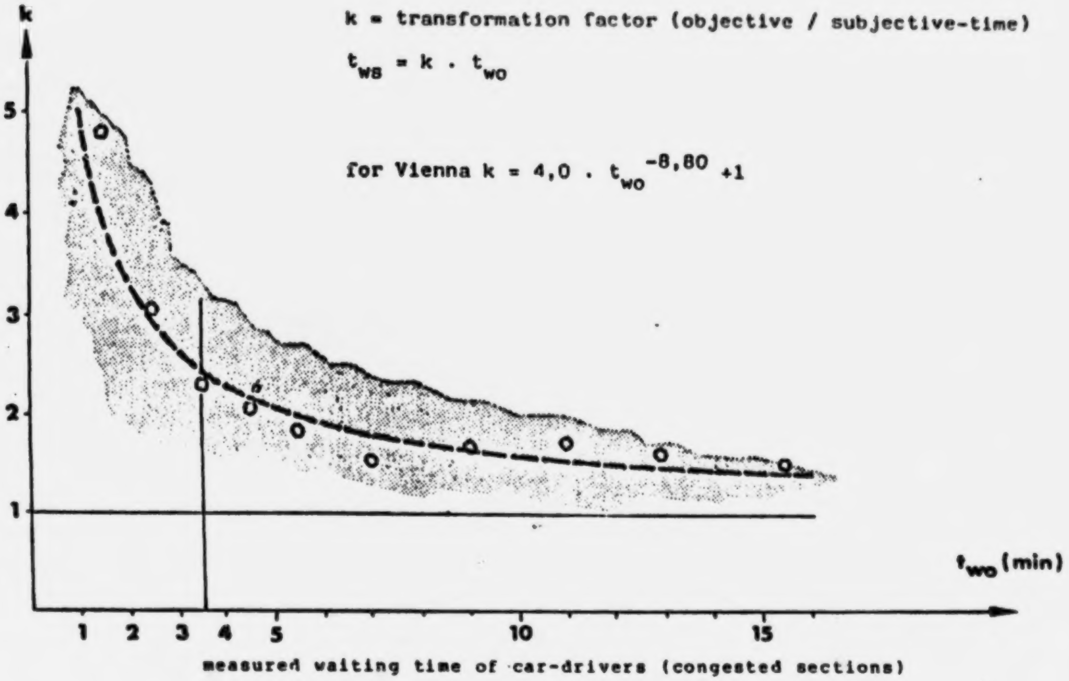

FIGURE 4

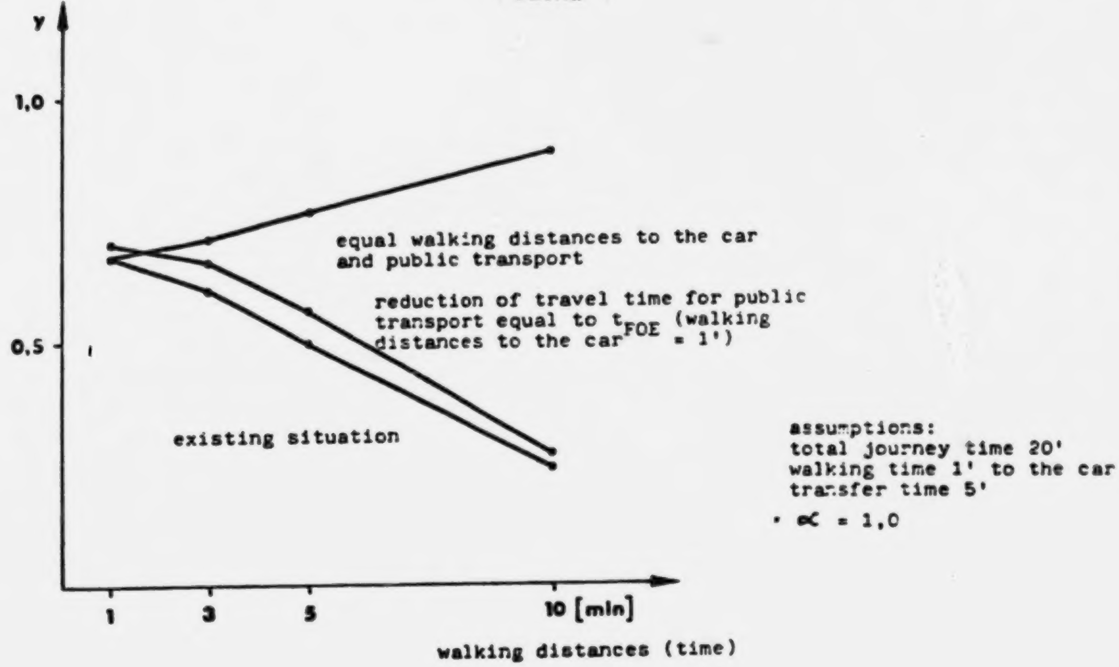

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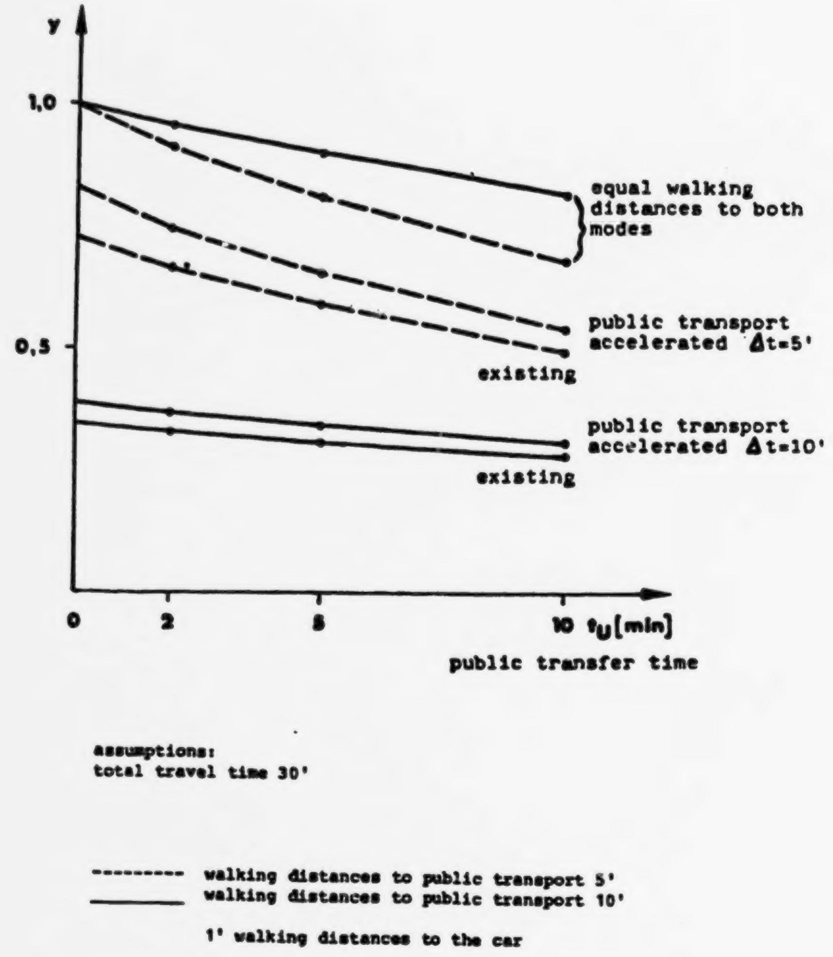
FIGURE 5



assumptions:
total travel time 30'

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FIGURE 6

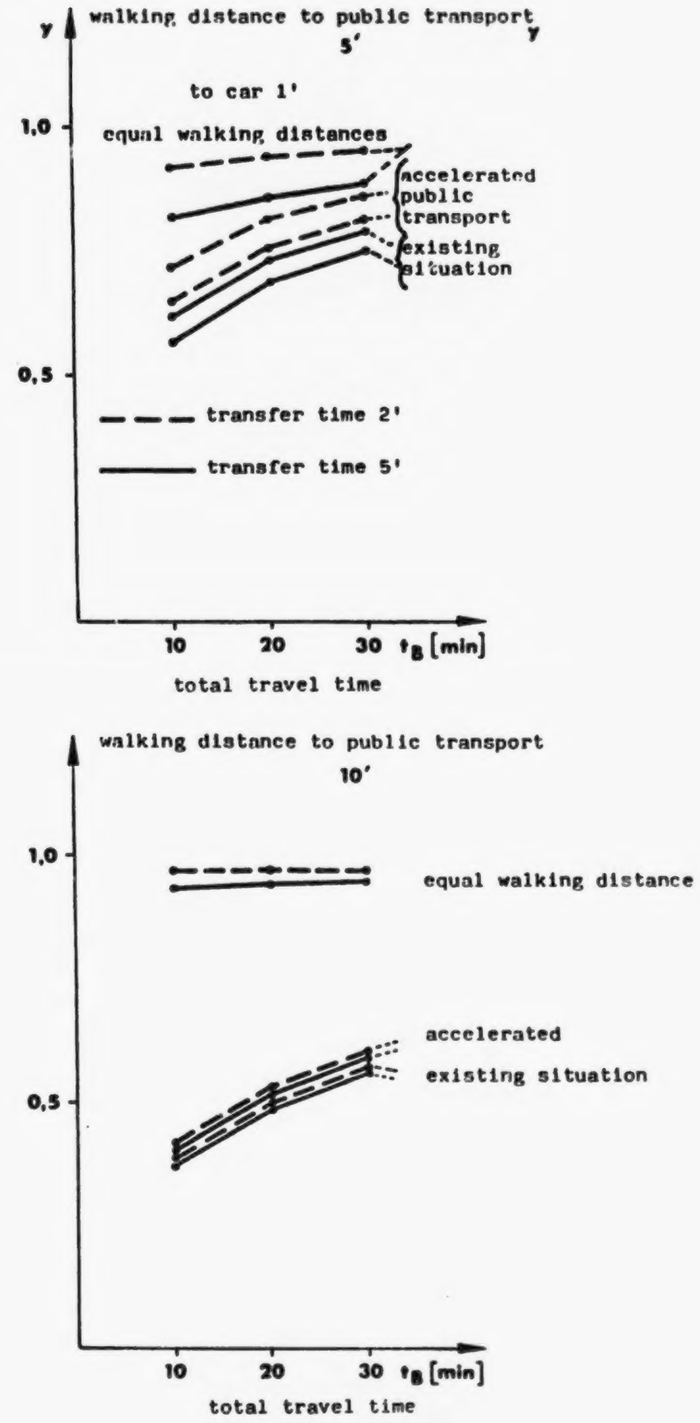

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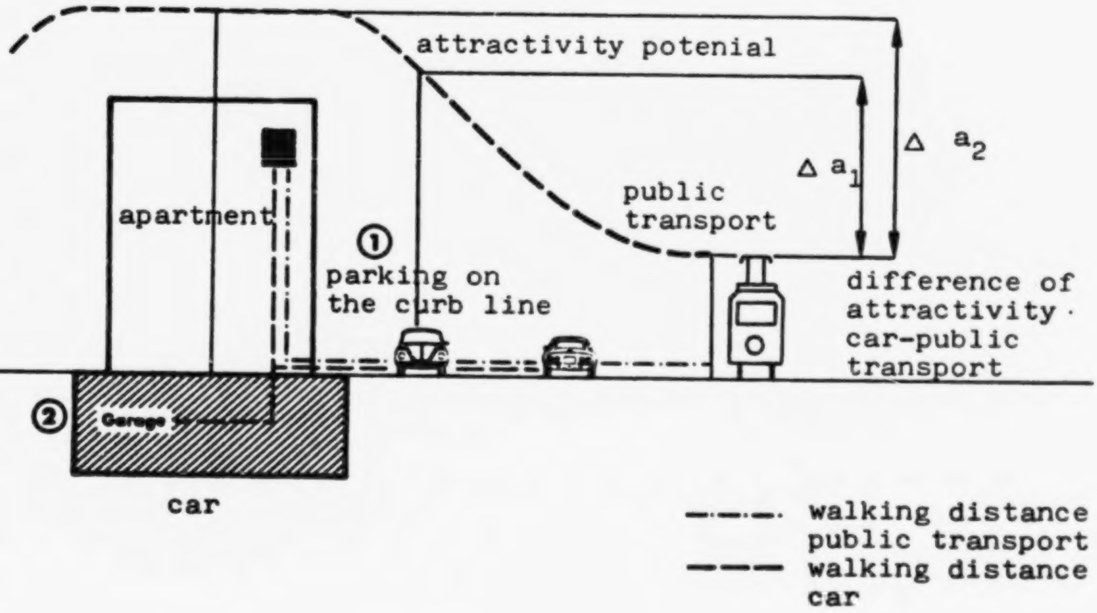
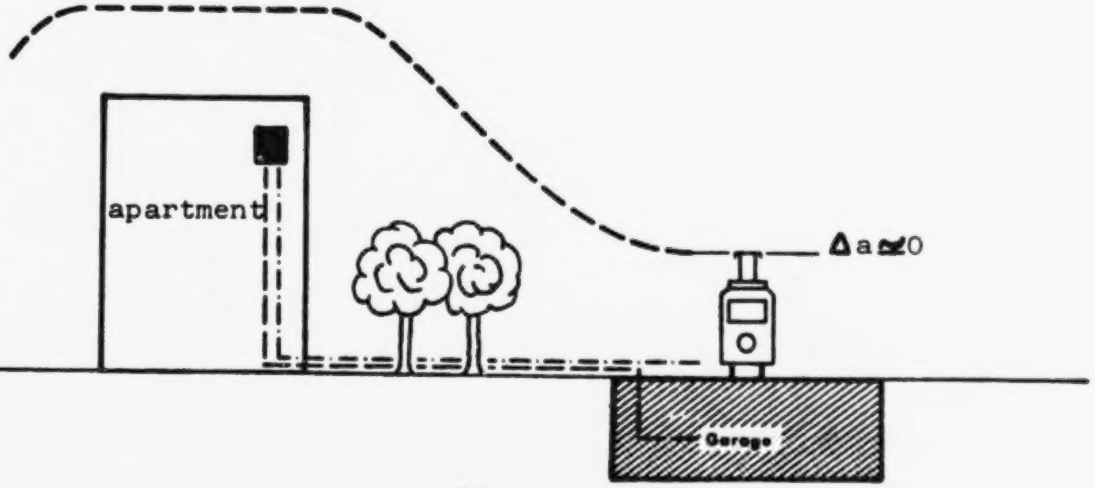
FIGURE 7

Existing Situation


attractivity potenial
Δ a₂
Δ a₁
public transport
apartment
①
parking on the curb line
difference of attractivity car-public transport
②
Garage
car
walking distance public transport
walking distance car

Proposed System


apartment
Δa≅0
Garage

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TOWARD A BETTER UNDERSTANDING OF THE LOCATIONAL CHOICE PROCESSES IN INTEGRATED LAND USE - TRANSPORTATION MODELS

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Abstract

The objective of this paper is to identify some of the research issues involved in the analysis of the impact of changes in transportation costs on the long-term development of the city. From studies of the impact of new rapid transit systems it appears that the effects are fairly subtle. During the 1960s and early 1970s most of the transportation models that were developed ignored the feedback to the land use allocation process. More recent developments in the fields of integrated models of the interrelationship between land use and transportation and individual choice models go some way towards solving the problems, but there are many outstanding issues.

In the paper the role of transportation costs in the decision process of individuals and households making locational choices are considered. More specifically, the following are discussed: whether the cost of travel to work is relevant in the choice of home and job, the number of stages that should be considered in the locational decision process, the required quality of the definition of the set of choices available, the interrelationships between locational and other household decisions, and the definition of the decisionmaking unit.

These ideas are being investigated in the context of a study of the impact of rail fare increases on the choice of home and job in London and South-East England. The evidence about the changes from aggregate data is conflicting, in particular whether a recent small increase in the use of rail represents a reversal of the previous trend of decentralisation, or is a temporary shift partly brought about by changes in the relative cost of alternative modes. The objective of the study is to examine the behaviour that is bringing about the observed changes. Consequently, surveys are being carried out of all workers at a number of larger employers in Central London and of current and former rail season-ticket holders in Hertfordshire to the north of London. This information will be used in the calibration of an existing aggregate model of the interrelationship of transportation and land use, and in the

development of microlevel models of the locational choice process and other decisions. Those models will be run in parallel so that the forecasting abilities can be compared and the implications interpreted. Thus, the analysis will assist in both the development of new analytical methods, and the understanding of the policy implications of increasing the cost of travel.

Introduction

The interaction between transportation development and urban form has been long recognised, yet analytical and forecasting effort has been concentrated on the influence of land use upon the generation of travel. For short-run forecasting, this neglect of the complementary influence may not cause serious problems, but in the long run the whole form of cities may be modified by changes in transportation policy and performance. In part, the differences between United States and European cities can be attributed to the variations in the means of access available during the evolution of the cities.

Despite the recognition that transportation plays a role in the development of urban morphology, there is little agreement on the magnitude of the effects. Indeed, there appears to be no general postulates of the effects of transportation on cities relative to other forces, such as the real estate market, planners or physical constraints.

Ironically, at the same time that the need for this type of model is being appreciated, the inadequacies of transportation demand forecasting methodology is being recognised. There is a movement away from the indiscriminate use of models toward consideration of the underlying processes that bring about travel. Researchers interested in the long-run effect of transportation can make a useful contribution to the debate and draw upon the lessons being learned.

The objective of this paper is to identify some of the issues. Rather than consider them in abstract, they will be examined in the context of a particular research project on the effects of changing transportation cost and draw upon the author's experience in a particular type of analysis.

Following from this, some of the general analytical issues will be specified, and then the methods of the project will be discussed. This will be used to identify the areas where further research is required.

The Effects of Rail Fare Increases in London and South-East England

The particular research project that has led to the generation of these ideas is concerned with the effects of rail fare increases on the choice of home and workplace location in London and South-East England (Kirby et al., 1979). Like most western cities, London has been exhibiting a process of decentralisation for many years. Indeed, this process was actively encouraged until recently, when the British Government recognised the development of the problems of inner city decay, and that the core of the problems was economic rather than environmental. Transportation has played a general role in urban problems by encouraging the physical spread of cities (Mackett, 1980a). In South-East England the role of British Rail, which transports over one-third of those who work in Central London, causes further complications. The cost of travel by rail has been rising in real terms, and the number of arrivals has been dropping. There has been a differential decline by short and long distance commuters. On the inner suburban services, patronage has been declining since the early 1960s, while the long distance trips reached a peak in about 1973. Consequently, the economy of London has become more dependent on long-distance commuters who are more sensitive to increases in the cost of travel. Many commuters are now paying over 1000 ($2400) per year for travel out of a pre-tax income of about 10,000 ($24,000). These people have little choice of mode. Alternative public transport modes are not available beyond the edge of the built-up area, and road congestion, lack of car parking facilities and the cost of gasoline make it impossible for most people to use automobiles. (In 1978 only 176,000 out of 1,067,000 travelled to work in Central London by automobile). Consequently, those who cease to travel to work by rail are likely to change location and so are unlikely to be attracted back to rail even if fares fell. At the same time as rail fares increase, automobile ownership has been rising, and new employment centres have been developing around London, for example near Heathrow Airport (SCLSERP, 1977); (Mackett, 1980c).

Clearly, the picture is complex. As rail fares increase, individuals have a number of choices available to them. The simplest alternative is to pay the extra money, but this may mean spending less on other goods or reducing savings, so there may be other effects on the behaviour of the households, for example, fewer recreation trips. Alternatively, one or more members of the household could take a job. This could be the rail commuter working part-time, or a previously non-employed worker starting to work locally. Either of these would affect the household, and to some extent, the local economy. As mentioned previously, it is difficult for those further out to switch mode, but those nearby may travel by alternative public transport, car pool, bicycle or even walk. The whole household can change its residential location, but a move towards London will mean an increase in housing expenditure or a drop in standards. If the person affected is not the head of the household, he or she may decide to leave the present household and set up a new one in London. The worker can change his or her workplace from central London to the local area, but may need to purchase an automobile to do so. If the commuter to London is a marginal worker, he or she might cease to be in employment.

There is a wide range of alternatives and not all will be considered explicitly by, or be applicable to, each household that is affected. There are, however, some important issues for analysis here. Firstly, a model that is intended for the representation of such effects should not, by its nature, exclude several of them, for example, by only allowing for a switch of mode. Secondly, there will be complex reactions, both within the household and in the local housing and job markets; while it may not be necessary to know about these for a particular example, there is a need to understand the nature of these repercussions. Thirdly, all the processes cited above could occur for reasons unrelated to the change in transport costs; hence, there is a need to establish the sensitivity of the various decisions (for example, to change home, to switch mode, to cease working) to transportation costs. The strength of the relationship will depend on a range of factors, so the population cannot be treated as homogenous. In order to forecast, this will mean dividing the population into groups that are relevant for the process under consideration and then forecasting the numbers in each group. Unfortunately, this simple approach which forms the basis of category analysis (Wootten and Pick, 1967) only works in the short run, because the relationship between the individuals with certain characteristics and their responses is unlikely to be constant, and the attributes may well vary in response to the changes in the supply side. An obvious example of this is as rail fares increase a household may purchase an automobile; so, not only the range of alternative responses to the original stimulus changes, but so does the other behavior both directly, through the new opportunities for shopping and leisure, and indirectly through the change in the level of disposable income. And so, there may be feedbacks to the original decision from the population in aggregate, back to the supply side, through the market mechanism, with further consequences for the individual in terms of the range of choices he or she is offered.

Clearly, there are some very complex issues for analysis. In the next section the extent to which various techniques are appropriate will be considered. Then research on the specific issues identified here will be examined and the particular approach being adopted to study the effects of rail fare increases in London and South-East England will be discussed. The paper will be concluded with some suggestions for the type of research required.

Analysis of the Effects of Transportation Costs Upon Location and Urban Form

This is not intended to be a comprehensive review of all the ways that the effects of transport costs upon the location of activities can be analysed. Rather, it is intended to examine how far the various approaches are useful in unraveling the complex, interacting processes discussed above. The methods may be useful for purposes other than that being considered here. Because the processes impinge on so many disciplines (for example, migration, residential location, job choice, the housing market and modal split), the emphasis will be on methods with explicit representation of transportation costs of individuals on location. See Mackett (1981) for further discussion of the issues involved.

One way to establish the effects of transportation costs on urban form is to monitor the effects of a large change on urban development and activity location. There have been several exercises on new rapid transit systems, for example, the BART system in San Francisco, in Munich in West Germany, on Tyneside in England, and in Glasgow in Scotland. BART was found to have had little impact on regional population and employment patterns (Dyett and Escudero, 1978), confirming evidence collected by Knight and Trygg (1977), and suggesting the need for the presence of other favorable factors (Knight, 1980). It may well be that the changes may be more subtle than were anticipated in the BART study. For example, in Munich (Kreibich, 1978) it was found that high income families tended to move outwards and exacerbated the separation of home and jobs, while reducing road congestion. On Tyneside (Transport and Road Research Laboratory, 1979) records are being kept of changes in employment level, planning applications and permissions, and changes in property values. Similar methods are being used in Glasgow for the changes in the rail system and the reopening of the Underground (Wicks, 1980). The Tyneside studies include indepth interviews and panel discussions to establish the effects of the rapid transit on their lives. (Unfortunately, financial restrictions may curtail much of this work.)

Perhaps the strongest tradition of work on the relationship between transportation costs and location comes from urban economics, where the work based on the trade-off between accessibility and housing space does not permit examination of the behavior of individual households. However, the work by Kain and Ingram (1975) has led to the development of the NBER Urban Simulation Model which permits the simulation of the urban housing market, including the effects of journey to work costs.

The conventional four-stage transportation model developed in the 1950s, and used in a major study in Britain as recently as 1977 with no significant changes to the structure, explicitly excludes the change in the spatial distribution of activities resulting from the transportation policy being modelled; that is, the land use component used at the trip generation stage is kept fixed for each policy. There are, however, several models which have overcome this problem. These have been based upon a framework similar to that of Lowry (1964), but considerably modified. Putman (1980) has iterated the highway congestion effects from the capacity restraint assignment with the location of population to represent the effects. Mackett (1976, 1979b, 1980b) has iterated the location of population, employment, and shopping with accessibility measures. Echenique at the University of Cambridge has used even more complex iterative schemes, incorporating a simple input-output model for Santiago (de la Barra et al., 1975) and rent-paying ability and location costs for Caracas (Echenique et al., 1974).

A major flaw with these models is that their aggregate nature does not permit explicit identification of the processes being modelled and so, does not include the representation of the interaction between the various decisions except in a fairly crude mechanical way. For some purposes this may be sufficient, but this has not been tested. By definition, the processes being modelled are long-term, and so testing the forecasting ability of the models requires data on long-term changes. The author has tested the model developed for the city of Leeds and found fairly good results in the sense that good statistical fits between the forecast change and the actual change over a five year period were obtained (Mackett, 1979a), but this permits little to be said about the ability of the model to represent the way people actually respond to transportation cost changes. For example, to test a policy, such as an increase in the cost of gasoline, the model is run twice, once with transportation costs kept constant in real terms and the second time with the price increase. The results can then be compared and the differences interpreted in terms of the cost change. In fact, the total number of the people living and working in the study area is kept fixed, and whilst the numbers allocated to each zone will be different in the two runs of the model, the total number being relocated is the same. In other words, the model is based on the assumption that the decision to allocate is independent of the change in travel costs, and that everyone's choice of home is effected by the change; although, in many cases this will be masked by the zoning system.

During the 1970s, the aggregate travel demand model mentioned above was superceded by the disaggregate model, in which individuals are modelled explicitly. This means that there is a simpler correspondence between the model and the behavior it is supposed to be representing. There are many disadvantages to these models, but like aggregate models, they permit the generation of ideas, and help refine methods of forecasting, particularly for specific problems rather than large-scale forecasting.

There have been several examples of the application of this type of model to the locational choice process, for example, Lerman (1976). The major problem, that independence between the alternatives being considered is a necessary assumption of the most common model form, has been solved by McFadden (1978). Whilst it can be argued that these models replicate behavior more closely, they are still calibrated against multi-dimensional revealed preferences, and so, not against the values put on alternatives that were considered and rejected. Indeed, the range of choices considered is not known; therefore, it is assumed that all choices are considered.

A range of issues has been raised. In the next section some of these will be considered in more detail.

The Issues for Research

The research cited above implies that there is a belief that transportation costs do play a role in the choice of location. It can, however, be only one of many factors. Much of the work in this field has been by sociologists who have concentrated on the housing needs of the family and the stage in the life-cycle. People asked to list their reasons for their choice of dwelling may not quote ease of access to work as a reason, because they regard it as an essential for any feasible choice. Given that the choice of location is a trade-off of various factors, it seems unlikely that each possible choice will be given a value of either one or zero on the basis of whether the workplace can be reached or not. In most cases, the decisionmaker will not have made the new work journey so he or she must make a judgement about the ease of travel induced by the changes. O'Farrell and Markham (1975) make the erroneous assumption that because commuters had not previously estimated the cost of travel, they did not include it in their locational decisionmaking processes. Several researchers have found direct evidence of the relationship, for example, Brown (1975) used household data for the Bay Area to establish that those with changes of workplace are more likely to change residential location and that a household is more likely to move if a new workplace requires an increase in work trip length. De Langen and Verster (1978) found that the opening of a new tunnel had a substantial impact on the location of households.

There is no clear agreement on the extent to which those choosing a new location take transportation costs into account. There is a need to establish the relative weight put on the various factors. It may well be necessary to break down the decision process into several stages. For example, the cost of travel may be important when a choice is made between areas, but not between dwellings in a particular area. This raises two issues: firstly, how many stages should be considered in the decision process, and secondly, how well do the choices have to be specified. On the first issue, the problem is often considered in terms of "push" and "pull" factors, implying a two-stage process of deciding to leave the current location and choosing a new one. In modelling terms it may be useful to have a preliminary stage of "considering moving," so that the population being considered during a particular time period is limited. As implied above, decisions may be made by choosing an area and then choosing between houses within the area. This is too simplistic because of the dynamics of the process. The decisionmaker may have to trade-off between a preferred house in an inferior area against the less-preferred house in a superior area, and weigh up the merits of a particular choice that is available against the possibility of a better one later, by which time the choice available earlier may have been made by another decisionmaker. This is a form of gaming, and there has been some work on the generation of choice sets from search processes (Richardson, 1980; Meyer, 1980). There has been work in the field of travel demand on the significance of the sequencing of decisions in which it was concluded that a simultaneous approach should be used. This is quite logical for travel decisions where the feedbacks between the stages can be treated as instantaneous (for example, from the routes available to the modal choice), but when locational choice is being included, not only do the decisions take a long time to come to fruition, but results of one decision may actually preclude certain choices from another, (for example, having chosen a new residential location, some job locations may be impractical and some modes are not available). Quite clearly, there is no fixed decision sequence corresponding to that implied in the four-stage transportation model. Not only are there a very large number of decision sequences, but also, the sequence may change for individuals over time, and as particular choices are made. Meyer (1980) has postulated a model in which recent migrants are relatively insensitive to the attributes of destinations, but the longer they resided in an area, the greater the likelihood that their spatial behavior would reflect the attributes of the choices.

Much of the work to date has treated each decision process individually. Even the choice of workplace and residence has been treated separately (Beesley and Dalvi, 1974) but as Brown (1975) and Weinberg (1979) have shown, they are intimately related. Furthermore, the interrelationships between the economic activities of the various members of the household must be considered, because there may be a partial trade-off between a gain in earnings by one member against the smaller decrease by another member (Sandell, 1977).

One issue that has not been considered explicitly is the definition of the decision unit. Usually the household has been used as the basis of both locational and travel decisions. For travel decisions, this is fairly straightforward because the choice made can be related to the current household structure, but for locational choice, the decision may be made on the basis of the expected structure, or may lead to a change, or even the formation or cessation of a household. Often the household is characterised by the concept of "stage in the life-cycle," whereby the age and economic status of the various household members is used to allocate them to categories. As discussed previously, "stage in the life-cycle" was found to be a useful explanatory variable for the decision to relocate and can be modelled directly (Clarke and Dix, 1981), but there is evidence that the conventional assumptions about life styles are invalid for many groups (Stapleton, 1980). For example, a survey may identify a group of young people sharing a dwelling who regard themselves as a household. However, their responses to a change in the cost of travel may cause one or more of them to leave. That decision may be made by one person alone, a couple, or a group of very close friends who wish to continue to share a dwelling. To predict the effect, information is required on the relationships within the group. A second example is the formation of new households by the marriage of two divorcees each with children, so that the existing household has not gone through the traditional linear life-cycle process.

In this section, some of the current ideas in research on the effects of transportation costs on locational choice, and hence on urban form, have been identified. The greatest need would seem to be for some rigorous empirical testing of the models. In the next section, some of the approaches to the project on the effects of rail fare increases will be discussed.

Toward an Understanding of the Effects of Rail Fare Increases

The processes that are being examined in London and South-East England were discussed previously. The project can be divided into two components--survey and analysis. The survey has been designed to obtain information on the type of issue identified in the previous section. Basically, the objective is to relate the decisions that have been made to the characteristics of the decisionmakers, the choices available and the prevailing cost environment. Information is required on all these. Since the decisions were made in the past, and the characteristics of the decisionmakers may have changed, it is necessary to obtain information on the characteristics at the time of the decision. Because the decision may have been made over a period of time (for example, the choice of a new dwelling), the characteristics at the time of the resulting action will be used as a surrogate. This may make recall by the respondent easier. The price of a dwelling may be remembered, but the complexities of the financing of house purchase cause problems. There are the problems of definition of the decisionmaking unit which require great skill and tact by the information-gatherer.

The complexities of the issues, budget limitations and practicalities, have restricted the scope of the survey. Initially, it was intended to obtain all the required information by self-completion questionnaire, but the nature and complexity of the information precluded this. However, insufficient funds were available to interview a sufficiently large sample for analysis; so a compromise was reached. Several thousand self-completion questionnaires would be distributed, and a question asked to establish whether the respondent would be willing to be interviewed in depth. As discussed previously, people can make a wide range of responses to rail fare increases; so the survey strategy had to include as many cases as possible, including some who had ceased to commute. Consequently, the strategy that was devised (Mackett, 1980d) had two parts. In the first part, eight organisations in Central London have distributed copies of the self-completion questionnaire to their staff. In the second part of the survey, questionnaires are being distributed to current and former rail season ticket purchasers who use six stations in Hertfordshire, three on a recently improved line, three on a poor quality line. From these responses a number of people will be selected and interviewed in-depth. These self-completion questionnaires will be analysed for significant differences between the two lines, between trips of various lengths, and between current and former season ticket holders.

The self-completion questionnaire contains questions on the present household, present and previous residential location and workplace location of the respondent, the date of the most recent changes and the number of changes over the last ten years, details on the present journey to work, assistance with the cost of travel and the cost of housing, and possible future changes of residential location. This information is being used in the selection of the sample to ensure that a range of potential alternative responses are included in those interviewed. The selection process also involves the definition of the group to be interviewed. In the self-completion questionnaire the respondents define their own households, given some simple criteria. From the pilot survey it is quite clear that, in some cases only, a subset of those defined as belonging to the household have been or would be involved in a relocation decision. Consequently, the decision unit is being defined prior to the interview. In fact, the interviewees in Hertfordshire will tend to conform more to the conventional nuclear family concept than in the pilot stage when some were selected because they were difficult cases. The interviews are of the person responding to the self-completion questionnaire plus those with whom he or she would be involved in a relocation decision. Questions are asked about the history of this group since it was formed or during the last ten years, whichever is shorter. The information obtained is such that the age, economic activity, and workplace of all members during the relevant period can be established. The locational history of the group, reasons for changing home and job, and details of income and expenditure on housing are obtained.

The information obtained will be used in the development of micro models of individual choices of location, drawing from some of the ideas discussed in the section titled, "The Issues for Research." It will also be used for the calibration of the macrolevel model of the interaction between land use and transportation (Mackett, 1979b). Research into the interrelationship between decisions over time is being carried out in the development of a game on a microcomputer (Mackett and Ong, 1980) whereby the player goes through a ten-year cycle of decisions, given information on his or her household, the choices available, the future rises in the cost of travel and mean house prices and mean incomes. Stochastic functions are used to determine the availability of particular houses and jobs to cause disasters and determine the rise in individual house prices and incomes. The information from the survey will be used to replace the present approximations with reality. The game will be turned into a forecasting model by replacement of the decision of the player by probability functions calibrated from the survey. The model will be used to replicate the decisions that have been made, and then the alternatives under different travel cost decisions will be found. These results will be compared with those from the aggregate model.

There is wide scope for further work within this project. However, resources do not permit the examination of several important issues, particularly the choices considered and rejected when decisions were made, the dynamics of the search process and the constraints on choices. It is intended to build upon experience gained to develop a further project to investigate these and related issues.

Conclusions

This paper has covered a wide range of research issues. It is a reflection of the dubiety of the field which itself represents the uncertainty in society today. Some trends and gaps can be discerned. There is a move towards increasing understanding of the underlying behavior, and away from the advocacy of particular styles of analysis. The nature of this field means that the responses are long-term, and so data must be collected over a period. One way to do this would be the monitoring of cohorts of population over time. Information is required on the choices actually made, the rejected alternatives, and the constraints under which the decisions were made.

There is a need for more critical evaluation of particular styles of modelling. One approach to this is to compare the forecasting abilities of the various models, to see how far the forecasts are functions of the model structure.

The uncertainty and apparent lack of direction should be used as an opportunity for determining the real problems that need to be examined, and a chance to develop new analytical methods, data sources and, above all, ideas.

Acknowledgement

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EVALUATION OF THREE PUBLIC TRANSPORT SCHEMES AND THEIR COMPARISON WITH BARCELONA'S TRANSPORT SYSTEM

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Abstract

The Barcelona dynamic transport plan started some years ago as a collaboration among transport engineers from the different official organizations in the area. It was not until 1980 that this work received official support. The instruments to be applied for the evaluation of the private and public transport system in Barcelona have been developed during the last several years.

The public transport objectives for this plan are, among others: major use of metro system, better accessibility to the outskirts of the city, decrease in general travelling time, better regularity of buses, and a new bus-network not too different from the present one.

The first step in the definition and evaluation of a new bus network is the design of three alternative bus networks, based on metro/train existing lines--a grid system, a radial-ring system and "magnetic force" system--which will be evaluated and compared in order to decide theoretically which is the best future system. The second step in the design of the future bus network (1982) consists of an approach to both the existing system and the theoretical best network.

The results show relatively small differences between the proposed networks. Should a new fare system be approved, with combined or hourly tickets, it would seem clear that the orthogonal bus network could give the most advantages with important changes in accessibility in the outskirts of the city. It will be necessary to add some radial lines to ensure the best communication with the surrounding cities and suburbs.

Introduction

Population growth in the Barcelona area during the last thirty years has definitely changed conditions for travel by car, bus, and metro. The population of Barcelona, within city limits, has grown from 1,280,000 inhabitants in 1950, to 1,855,000 in 1980. A steady growth has also occurred in the metro system, from 10.8 kilometers and 23 stations in 1950 to 46.6 kilometers and 72 stations in 1980. Metro service has only recently been extended to neighboring towns which are part of Barcelona's high density urban prolongation. Metropolitan bus service, which follows the pattern of the old streetcar lines, has been modified only by the addition of a few new lines. Since suburban bus service is privately owned, most of the new bus lines are used to provide access from suburban areas to the central business district (CBD).

Barcelona's transportation needs cannot be addressed within the inflexible framework of the Transportation Act of 1947. Bus service, now 25 years old, offers fares held low for political reasons. The low fares have had a negative impact on service. It is only in relation to the issue of bus fares that the Transportation Act has been influential. The private bus lines enjoy a high degree of protection.

One of the main transportation problems is caused by the adoption of single bus lines in areas where demand is great. The problem is worsened by the lack of adequate bus and metro networks. In addition, the lack of transfers and flash passes is a problem for transit riders.

In sum, declining public transit ridership is due mainly to increases in automobile use, deteriorating service caused by "frozen fares" and poor accessibility. (See Table 1)

TABLE 1

COMPARATIVE FIGURES 1950-1980 IN BARCELONA

	1950	1980	Increase
Inhabitants	1,280,000	1,855,000	45%
Total Vehicles	27,000	700,000	26 times
Passengers in Bus/Year	373 M	219 M	- 41%
Passengers in Metro/Year	81 M	243 M	200%
Motorization	21	377	18 times
Trips in P. Tr. per Inhabitants/Year	455	249	- 45%

Actual Transport Policy

The Barcelona area's high population density and increasing use of cars causes severe congestion. However, when more streets are made accessible to cars, parking problems multiply and problems increase for public vehicles, delivery vans, and pedestrians. When conditions are improved for public transit vehicles and pedestrians, queues of private cars cause congestion of such magnitude that it can affect the entire city. One of the causes of the congestion is the shortage of parking spaces and garages in the municipality. A three-year survey on parking facilities in Barcelona found that the city can only accommodate 500,000 vehicles, which results in a shortage of 200,000 spaces.

Another reason for a new transportation policy is that the publicly-owned transit companies have huge operating deficits. During the summer of 1980, for the first time in Barcelona, politicians and transportation specialists joined forces to develop a transportation policy with the following main characteristics:

- redesign of the bus system to improve accessibility for poorly serviced areas, given the existing metro system;
- changes in the fare system including transfers and flash passes;
- improved pedestrian facilities including pedestrian-only streets and zones, widening foot paths, and improved conditions at street lights;
- changes in procedures for goods delivery, including sufficiently marked loading zones;
- increased parking space, particularly for residential areas;
- restrictions, via traffic laws and parking regulations, on the use of private cars.

The Dynamic Transportation Plan

A new, detailed transit plan is being developed as a continuation of the earlier transportation policy development activities, not as the total ideal plan for the future, but nevertheless, dynamic because of the amount of policy detail which is provided. Following completion of the plan, the details will be submitted to the politicians in an attempt to maintain an open discussion, not only of the plan itself but also of each implementation stage.

A study of Barcelona's future bus system requirements is included in the plan, and the first stage of development involves a definition of the main bus lines. In turn, these lines will guide the final design of a new alternative bus network. Since many important technical decisions have to be made, it is important that the technical proposals are as consistent with the policy and the global plan as is possible. Although the plan is not complete yet, performance characteristics drawn from existing conditions are processed continuously and incorporated into the decisionmaking process.

Evaluation Model for Transportation Alternatives

Barcelona's current situation in relation to the public transportation system has demonstrated the need for a new focus on bus and metro systems. This is so because of the changing patterns of transit ridership, the operating deficit, and the need to enlarge the metro system. Since half of the metro system kilometers were constructed by the State and were not planned within the integrated transit system, it is difficult to change the configuration of the present system. This means that, to a certain extent, the existing and planned metro lines will define the need for a complementary bus network.

It is within this framework that it has been necessary to develop a wide range of transportation models, to collect data, and to evaluate possible alternatives. At the same time the politicians are pressing continuously for the formulation of alternatives but without providing the necessary funding and time for the elaboration of alternatives. Consequently, the public transportation model represents only one phase of the total program.

During the last decade some of the basic components of the model have been developed, but most of them relate to private automobile use. A lack of reliable data on trip generation, income by household, rates of car ownership, job locations, and other trip-generating variables is one of the most serious problems related to transportation model development in Barcelona. This lack of data means that it has been necessary to adapt models to existing information rather than collect information for transportation modeling.

Nevertheless, a series of instruments has been developed to accommodate the following categories of information:

- population and motorization standard files
- transportation/census O-D data
- home interview data
- transit stop interview data
- traffic counts
- distribution models
- assignment model for automobiles

- graph creation, handling, files, and programs
- public transportation evaluation model
- public transportation assignment system

The existing part of this complex of programs and models relies on data, results, and experiences gleaned from earlier activities. Moreover, a graphically portrayed description of street and rail networks, defined by nodes and links, is a very important input.

In Figure 1 the scheme of major steps in the evaluation and assignment model, with its four main phases, are indicated as follows:

1. description and fitting of the graphs and line files for the model
2. the algorithm of the shortest path
3. computation of evaluation rates
4. assignment of trips to lines and links

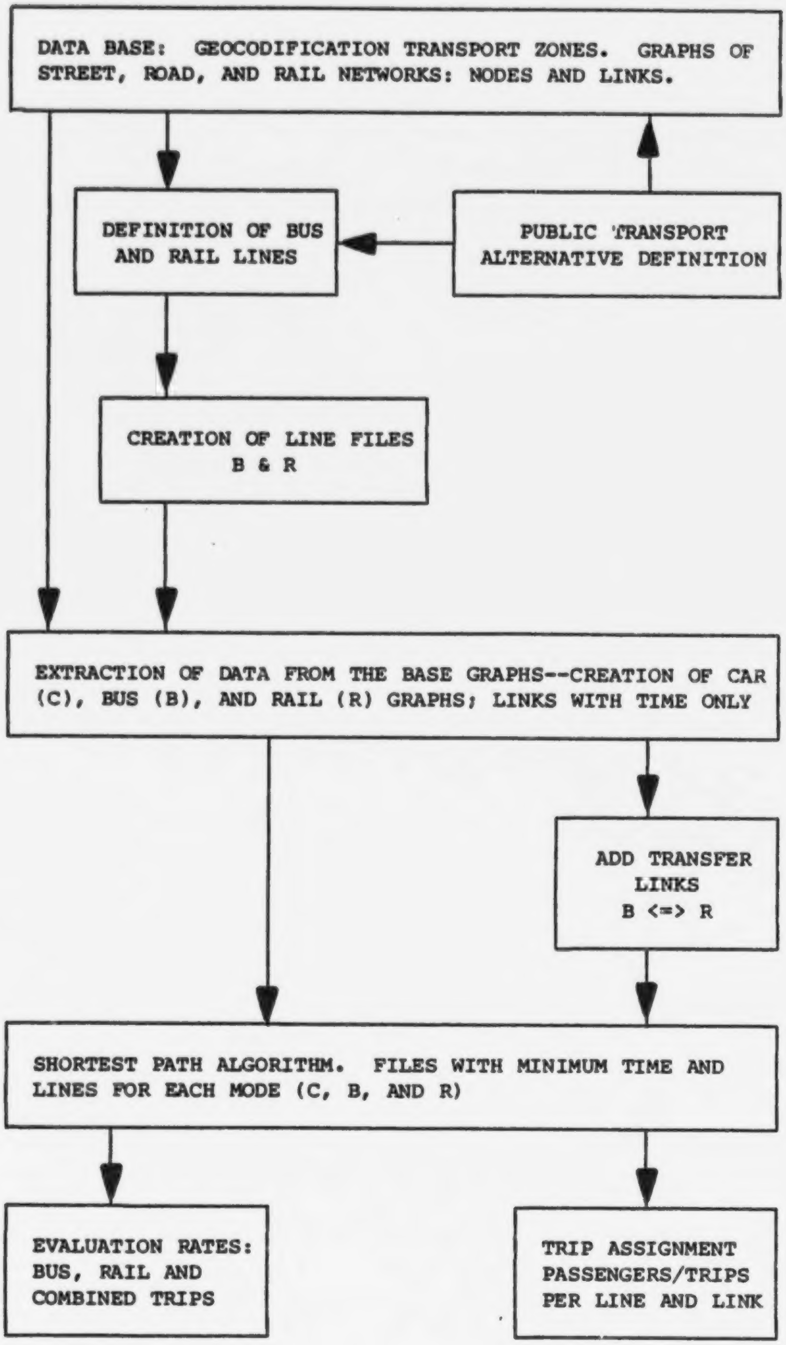
Description and Fitting of the Graphs and Line Files

One of the completed tasks is the definition of basic graph files for the whole area of Catalunya. The graphs are sufficiently detailed, containing up-to-date information in Barcelona and a couple of other cities where traffic studies have been carried out. The rail graph for the Barcelona area is informationally up-to-date, but the street graph only exists as a skeleton without physical characteristics. The line files are up-to-date for Barcelona as are the rail files. By concentrating the efforts within Barcelona in the first step, the graph and line files serve directly as input. In a few months, it will be possible to use the graphs for the whole metropolitan area. First, a program which is used to extract information from the basic graph and line files has been defined. In turn, graphically portrayed information per link, such as length, speed, type of link for speed/traffic volume curves, capacity, and lane information is supplied. Three graphs of this type have been created for actual situations: metro, bus, and car/pedestrian. These special graphs are extracted from the base files for each new bus or metro alternative.

Transfer nodes and links corresponding to the bus system are added to the metro graph in order to create the necessary connections between the two systems. The graphs which serve as input for the algorithm are computed from length and speed information. These graphs only show the time it takes to pass each link with given traffic conditions. It has been decided to use trip time as a base for the evaluations for three reasons:

1. The area studied so far is fairly homogeneous, both in land use and density as well as in street configuration.

FIGURE 1


DATA BASE: GEOCODIFICATION TRANSPORT ZONES. GRAPHS OF STREET, ROAD, AND RAIL NETWORKS: NODES AND LINKS.
DEFINITION OF BUS AND RAIL LINES
PUBLIC TRANSPORT ALTERNATIVE DEFINITION
CREATION OF LINE FILES B & R
EXTRACTION OF DATA FROM THE BASE GRAPHS--CREATION OF CAR (C), BUS (B), AND RAIL (R) GRAPHS; LINKS WITH TIME ONLY
ADD TRANSFER LINKS B <=> R
SHORTEST PATH ALGORITHM. FILES WITH MINIMUM TIME AND LINES FOR EACH MODE (C, B, AND R)
EVALUATION RATES: BUS, RAIL AND COMBINED TRIPS
TRIP ASSIGNMENT PASSENGERS/TRIPS PER LINE AND LINK

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2. There are only single fares in the Barcelona Public Transport System with one ticket for metro, which includes metro-metro transfers, and one ticket for every bus ride.

3. The transfer costs bus-bus and bus-metro can be translated into time although it is difficult to factor different parts such as waiting time, walking distances, ticket costs, inconveniences caused by changing, interruption of trip, etc.

With the exception of the waiting time and well-defined walking times (both defined in graphs), the transfer has been estimated to have an importance equivalent of two to six minutes, using results from different trip-surveys which will be carried out this spring. Additional studies of transfer values are required to tighten the two- to six-minute range.

The use of time, or minimum time (shortest paths) to determine the route from one zone or node to another in the city, is also based on the assumption that usually public transit passengers try to minimize the time of the journey, which seems rather logical considering that approximately two thirds of total trips taken in the city are non-discretionary (trips to and from work and school).

The Algorithm of the Shortest Path

The shortest path algorithm for public transportation has been developed using experience from the algorithms for cars studied over the years and described by Garcia and Thorson (1979).[2] The details of this algorithm provide information on minimum time from origin, precedent node in the subpath, and lines which permit execution of this subpath. Each subpath may consist of one or many links. If a minimum path can be realized by one line, it means that there will be three subpaths: radius, line, and radius.

The shortest paths will be computed separately for each node. To enable the computation of the minimum possible path in combined metro bus trips, the paths will be computed both for centroid (traffic zones) and for the transfer/nodes links as defined in the graphs, to connect two possible transportation systems.

Each time a new line is introduced in the minimum path, the waiting time at the bus stop or metro station (half of the headway) will be added to the next node on the line. In case of a transfer, a penalization will be added, which will include the inconvenience value of a transfer and/or the extra cost of a new ticket, as mentioned above.

Computation of Evaluation Rates

Once the shortest paths have been computed, based on the networks and the trip matrix, different rates of evaluation can be calculated and it may be desirable to analyze the evaluation rates.

The most important evaluation rates are some of the defined accessibility values. These rates are only significant in large and homogeneous urban areas. For minor areas, a severe distortion in the borders is to be expected.

Mean accessibility: The accessibility of public transportation service computed as a base of the minimum interzonal time, or general cost for a trip, (C_{ij}), for each zone (n zones):

$$AM_i = \frac{1}{n-1} \overset{n}{\underset{j=1}{}} C_{ij}$$

This is also the mean value of the columns or rows in the time matrix and expressed by the mean time for one trip or each of the other n-1 zones in the area. It must be stated that accessibility values are subject to some inaccuracies due to the natural limits of the study area; the simplification of the centroid-zone-radius system; and the simplification inherent in graphs, lines, and other basic symbols. However, accessibility provides an idea of how different zones are related to each other and of the time spent in travel by inhabitants. Accessibility values are especially interesting when comparing alternative networks, since alternatives are subject to the same basic errors. Thus, comparative changes in accessibility are basically reliable. The problem related to the accessibility concept is under consideration, and it may be more accurate to subtract theoretical accessibility rates, computed for a totally homogeneous area with a specific type of network, from real values.

One facet of the problem is available transportation service and another is how users spend their time in transport. With a known trip matrix (the performed demand), the minimum time matrix can be weighted with the trips (T_{ij}) and the performed accessibility is found:

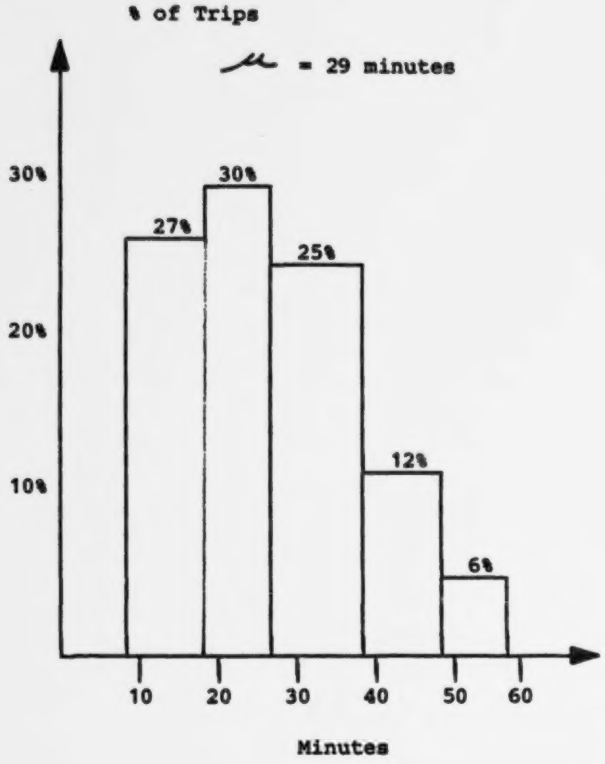
$$AP_i = \frac{\overset{n}{\underset{j=1}{}} C_{ij} \quad T_{ij}}{\overset{n}{\underset{j=1}{}} T_{ij}}$$

Accessibility values might be computed for each trip matrix or attraction value at zones j. The accessibility rates must be compared to a standard value/values, defined by politicians and technicians to obtain its real significance. These rates are only mean values and for more detailed analysis it is important to know the distribution of trips with specific trip durations--distributions which must be defined in advance as a minimum standard for public transportation service.

A standard distribution has been established in order to compare the different accessibility rates, with the following macro conditions: at least 50% of trips should have journey times less than 30 minutes and no trip should last more than one hour. These criteria can be transferred to the accessibility curve which is shown in Figure 2. This curve will be used then in an analysis of results of the evaluations described later.

FIGURE 2

POSSIBLE MINUTE STANDARD FOR JOURNEY TIMES



Trip types also have been categorized and journey times determined, including the number of transfers necessary to execute the trip with a minimum of time. These computations comprise another interesting evaluation factor.

The mean number of transfers and the modal distribution of trips are computed for each zone, such as 30% by B (bus), 15% by B-B, 20% by M (metro), 20% by M-M, 3% by B-M, and the rest by other combinations of modes. The total time spent in this system as well as the global mean time per trip has been calculated as a complement and gives a general value representing users' travel time. The cost of trips as a mean value for each zone and for the whole city can be computed according to trip type and trip cost.

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Assignment of Trips to Lines and Links

The most direct path through the system with its subpaths, lines, and trip types, as previously defined in the evaluation model, serves also as the basis for the assignment of trips to the network with the single lines originating from links which complete the line. With several possible choices of lines to serve passengers in a given subpath, it has been decided that trips will be distributed in an inverse proportion to line frequencies.

In the present version of this assignment program, output has been limited to a list of passenger links per line and a graphic for each line which will indicate trip costs for different sections of the line. The assignment part of the model has not been used for the analysis described in this paper.

Previous Evaluations

The first results of evaluations of the actual network and some proposed alternatives have been described by Garcia and Thorson.[3]

The influence of proposed metro extensions and of the proposed orthogonal grid network were evaluated by using the model.

Additional information concerning non-discretionary travel, taken from the last census of population, was used to calculate some of the evaluation rates for the trip matrix. During morning peak hours (6:00 - 9:30 a.m.), 385,000 trips were taken. This matrix will also be used for the evaluations described in this paper and to clarify comparisons of alternatives.

The main finding from this first evaluation is the importance of the extension of Metro Line IV, and also that it is impossible to define a new bus network which, based on trip matrix drawn from actual experience, offers several advantages. For example, some advantages are less trip time, fewer buses, and better frequency, with a slight increase of the number of transfers. A reduction in mean trip time or improved accessibility was shown in 78% of the traffic zones.

The next step in the public transportation evaluation process has been the computation of accessibility rates and passenger charges (assignment model) for six different suburban metro routes, and it has been possible to decide quite clearly which part of the new lines must have priority.

It has been necessary to revise the metro plan in relation to the transfer of the authority for metro construction from the State to Generalitat of Catalunya, the local Catalan Government.

Design of New Alternatives

As mentioned, the first results of the new evaluation model were produced and analyzed in 1979. The political decision process is slow, and until now the interest in further studies has been unfavorable. The immediate need for bus system redesign, with a possible extension of the metro network, and users' demands together with the enormous operating deficit have made evaluations of possible new networks an urgent matter.

In this context and considering benefits of different bus network structures, we have defined two new theoretical networks which allow comparisons of different strategies to be made.

Should the networks be defined in a totally theoretical sense, with the base in a homogeneous area, the distance between the lines could be more or less the same with different networks. However, difficulties found in the real street network make it impossible to follow the theoretically planned lines.

Given the lack of certain street links between areas of the city, it helps to understand why there are notorious differences between the plan and the alternatives defined as input. In Figure 3 are shown the main characteristics of the present bus network as well as three proposed alternative routes.

The redesign of the systems has been limited by the decision to use the existing network with a maximum profit and to avoid planning new streets in the city. The orthogonal grid network has been mentioned and is defined in accordance with the new arterial street network to be established in the approval phase. This network presupposes specialized street activity with a segregation of types of activities and creation of super-blocks or neighborhood units. The networks consist of 11 horizontal and 18 vertical circuits in the city. This design offers the users the possibility of making trips with a maximum of one transfer.

With regard to city accessibility, Barcelona has a clear radial, concentric layout, even when a great part of the center is absorbed by an orthogonal grid system. Hence, as a second bus alternative, a radial concentric network has been proposed with all rings sharing the port frontier.

Five rings plus twenty-two radial lines have been established in this first effort, with the obvious problem of an excessively high population concentration in the city center and an excessively low density in the outskirts. With fewer lines and line lengths, walking distances to transit will increase in the outer metropolitan areas.

Finally, it is intended that this work define a network with the characteristics of magnetic force lines. This is due mainly to the fact that the city needs a higher line of concentration in the center than in the outskirts. The parts of the city with a poor street scheme (for example, the Old City, Garcia, Sants) are the basis for some restrictions on the orthogonal network and combine better with a "magnetic" shape. This network consists of 21 lines with 8 horizontal and 13 vertical. As indicated in Figure 3, this network with lines along Ring II does not fit into the theoretical base.

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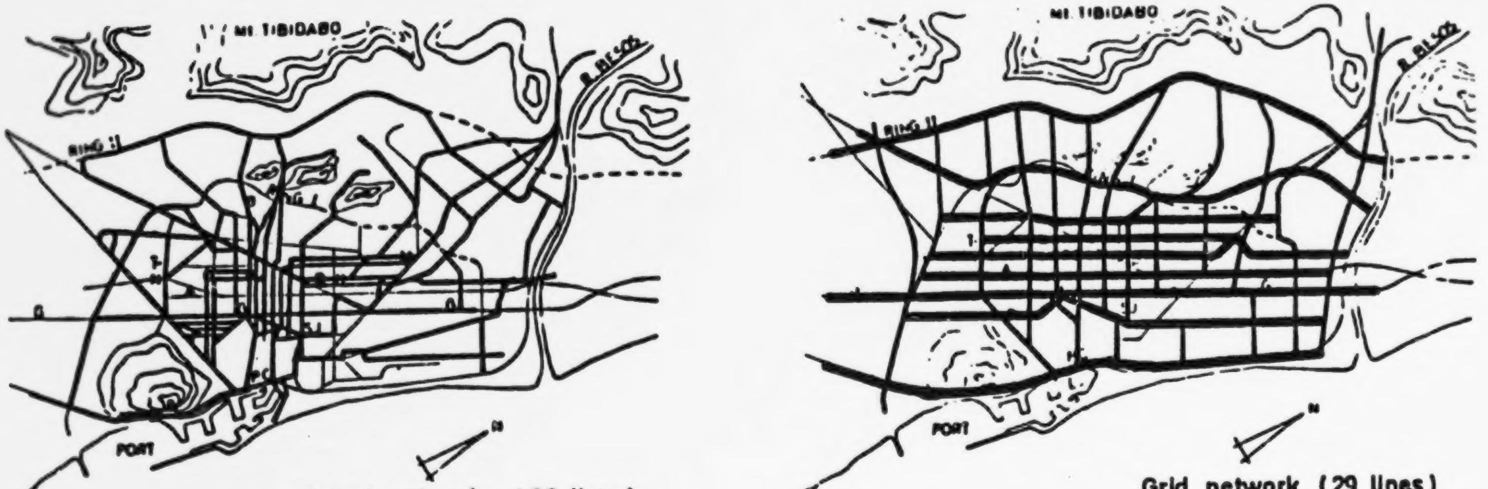
MT. TIBIDABO
RING II
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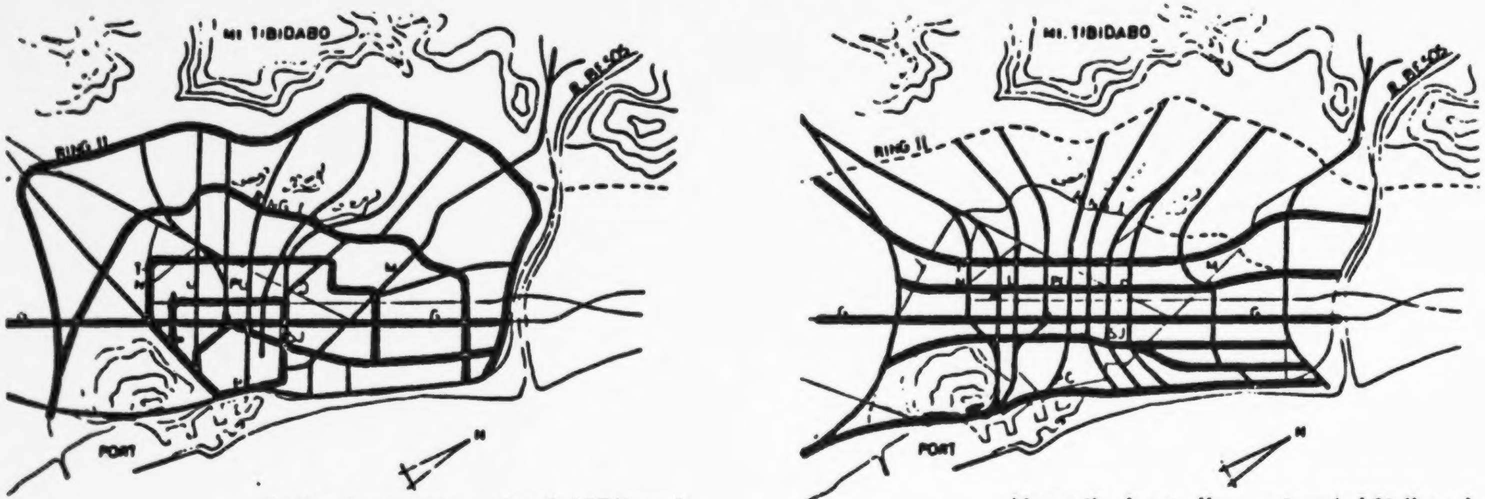
N
G
MT. TIBIDABO
RING II
R. BESOS
PORT
N

Actual network (80 lines)

Grid network (29 lines)

Bus networks, defined and evaluated for the purpose of proposing the best future network.


MT. TIBIDABO
RING II
RING I
R. BESOS
PORT
G
N
MT. TIBIDABO
RING II
R. BESOS
PORT
G
N

Radio-Concentric network (27 lines)

Magnetic force line network (21 lines)

FIGURE 3

Results of the Evaluations

The metro system used in combined bus-metro trips and the metro as a competitive public transportation system caused no time disadvantage. The only changes introduced have been in the adjustment of links which connect metro to bus because of variations between bus networks. The disadvantage caused by transfer situations has been given a value of 360 seconds for three trip types--bus-bus (B-B), M-B, and B-M--while M-M trips, as mentioned above, have caused no bus system penalty. Some important characteristics of the four have been summarized in Table 2.

Even when the number of lines is reduced to a third of the present figure, it is possible to maintain a high degree of service with a much lower superposition of lines in the same link.

TABLE 2

OVERALL VALUES DESCRIBING BUS NETWORK EVALUATIONS

	Present	Orthogonal	Radial	Magnetic
Number of Lines	78	29	27	21
Length of Lines	1,087 Km	537 Km	488 Km	445 Km
Length of Street Fronts	440 Km	394 Km	335 Km	303 Km
No. of Lines per Link	2.5	1.4	1.5	1.5
No. of Buses Necessary	659	539	418	371
Mean Bus Speed	13,6	12.7	14.9	15.3
Mean Bus Frequency (Minutes)	8	5	5	5
Total Time Spent, Hours	195,420	182,568	185,646	191,017
Total No. of Transfers	199,000	219,000	186,230	190,820

With theoretical systems, it must be admitted that it is difficult to reach a high enough level of service. The fleet of buses needed for the networks is more or less proportional to the number of lines in the three new networks. As shown in Table 2, the difference, either in total time spent or in number of transfers, is not very important. In equal speed circumstances, there will be greater time advantage for the orthogonal network which, on the other hand, produces a considerable number of extra transfers.

The evaluation model is sensitive to changes in speed conditions, which are shown in Table 3, where the two networks (present and orthogonal) with the lowest bus mean speeds also show the highest proportion of trips on metro.

One part of the difference in speed conditions for radial and magnetic networks is caused by street works with a certain inversion. A better bus network structure produces a decrease in the number of bus trips used only as a means to reach the metro.

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TABLE 3

PERCENTAGE OF DIFFERENT TRIP TYPES, PENALIZATION 360 MINUTES

Type of Trip	Present	Orthogonal	Radial	Magnetic
M-B	0.5	0.6	0.5	0.5
Other M-B Combinations	1.2	1.1	0.7	0.6
B-M	3.4	1.6	1.8	1.9
Other B-M Combinations	2.9	0.8	1.0	1.5
B	33.7	24.8	36.6	36.1
B-B	7.4	12.3	10.6	14.7
Other B Combinations	0.4	1.9	0.4	0.3
Total Bus	41.5	38.9	47.6	51.1
M	22.3	25.7	22.1	19.4
M-M	24.3	26.2	23.1	21.7
Other M Combinations	2.7	4.0	2.1	2.1
Total Metro	49.3	56.0	47.3	43.2
Trips without Transfers	55.9	50.5	58.7	55.5

An analysis of the results shows that, from a journey point of view, the orthogonal network is more interesting than the others, but the high number of transfers must be amortized by some special lines to attend high directional flows, and it is impossible to propose a network like the orthogonal one without thinking of a combined fare system (transfer).

As a result of the comparisons of two zones and four networks, trip times are shown. The most central zone (Pza. Catalunya) and one from the residential outskirts have been chosen (Bº Besos). (See Figure 4) As can be seen in the Barcelona area, the differences between the alternative networks and the present situation are minimal in the center of the city, whereas in the outskirts the accessibility is better with an orthogonal network, and the mean journey trip length decreases from 45 minutes with the present network to 32 minutes with a radial network, or 31 minutes with a magnetic to 30 minutes in orthogonal network.

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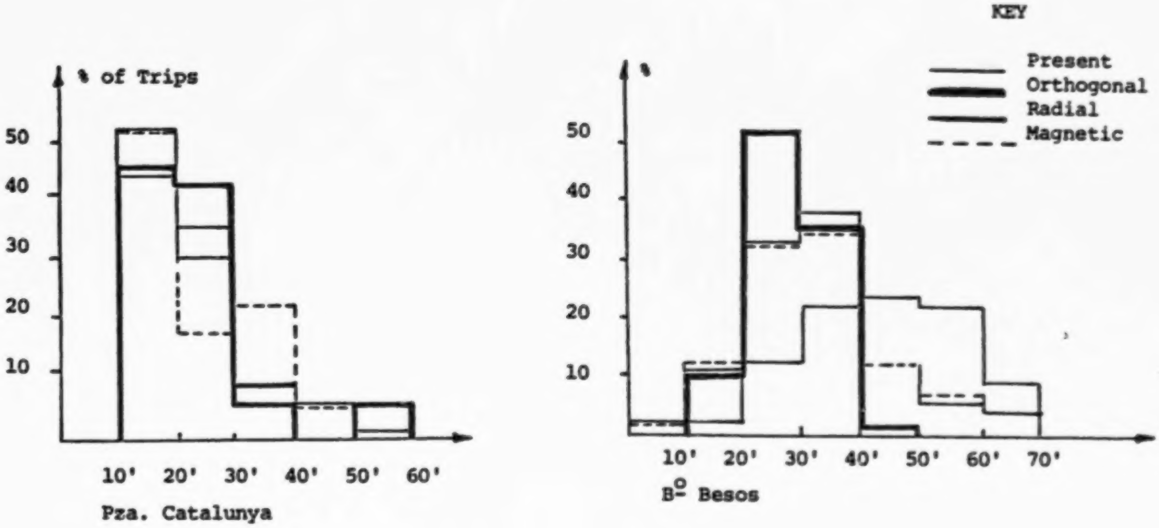
FIGURE 4



Conclusions and Further Work

The evaluations of bus networks which have been described seem to indicate that combinations of the orthogonal and the radial types of networks might best provide accessibility to users. Nevertheless, it is important to factor in the conditions of passengers as pedestrians and also walking distances from trip origin to bus stop. Thorson (1977) and Garcia and Thorson (1980) (Reference 3) demonstrated that the orthogonal network, with up to 450 meters between one directional bus line and bus stops (in the line-intersections), may serve nearly all possible users, with acceptable walking distances. This fact is not true, of course, in the radial line system which must be adapted to solve this problem.

At the end of 1981, the new network should be decided based on both the radial and orthogonal approaches. Transportation planners will attempt to adapt the present network to an ideal structure without too many changes in the system as it functions at present and is known by the users. In the evaluation of networks, the municipal network, which forms the Barcelona area, will be included in a schematic way. It is our hope that this evaluation may lead to a better understanding of the problems of public transportation as seen from the users' point of view as well as from the management point of view. Given the structure of the areas with its well-defined access corridors (to Barcelona), one can conclude that the radial system will fit even better when the entire metropolitan area is included.

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Acknowledgements

The Transport Plan, together with the results from its first phases, has been supported by colleagues from the different transport authorities of Barcelona: Municipality, Transport Companies, Greater Barcelona Council, and Generalitat of Catalunya. To enumerate all of them would be almost impossible. We would like to thank them for their participation with a special acknowledgement to Mr. Rosello and to Mr. G. Garcia for their technical and informational support.

The points of view expressed in this paper are those of the authors and they do not necessarily coincide with those of the Town Hall or the Transport Companies.

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THE RELATIONSHIPS BETWEEN LAND USE, RESIDENCE, AND WORKPLACE MOBILITY AND COMMUTING: AN INTEGRATED APPROACH

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Abstract

In the western part of the Netherlands (the so-called Rim City Holland and its surroundings), a migration of people from larger cities to rural areas is linked to a rapid increase in long-distance commuting by car. The polynodal structure of the area facilitates a spread of housing and workplaces which entails very large traffic flows and numerous inter-crossing relations.

The national government has defined a policy to forestall a further growth of suburbanisation and commuting. To achieve that goal, new locations of residence and employment should be developed as much as possible within a number of city regions and in such a way that the use of public transport and slow transport modes (bicycling and walking) will be feasible. Within each city region, there should be an equilibrium between living and working.

Noting the uncertainties connected with the realisation of these policy objectives, a study was undertaken of the interrelationships between migration and work-change behaviour and commuting. These principles were intended to avoid the pitfalls associated with the use of large-scale static transport and allocation models.

Results of the study are discussed with an elaboration of the approach to be followed in subsequent stages. The descriptive part of the study has been carried out with data obtained from national Labour Force Sample Surveys. These two-yearly surveys appear to be a very useful source of relevant information for monitoring purposes.

An extensive household survey was taken, providing data needed for the explanatory analysis, which in turn will provide a basis for methods for policy evaluation. An experiment with a simple model is carried out to provide information for the evaluation of policy alternatives currently being considered by government planners.

Urbanisation in the Netherlands

The spatial structure of the western part of the Netherlands has largely been determined by the socioeconomic developments during the period since the Second World War and can be characterised as a progressive spread and spatial separation of living and working, linked with a growth, both in number and distance of commuter moves, made possible by the fast increase of car ownership due to the increase in prosperity. The shift in modal split towards the car in commuting traffic was achieved at the expense of public transport and slow traffic (walking and cycling). To cope with the ever larger traffic flows, the road infrastructure had to be considerably extended, which meant a new demand on scarce space with unpleasant consequences, particularly within the towns, for the quality of the environment. Another negative result was that the exploitation deficits of public transport (a burden on the public budget) rapidly increased.

This process is found in all countries with a highly developed economy. In the Netherlands the negative aspects are mainly manifested in the western part of the country. Moreover, the development there should be looked upon as a specific variant because of the historical spatial structure from which it started. Indeed, in Western Holland there is not one large central city with its surrounding zone of influence, but rather a region containing several towns at a relatively short distance from one another; together, these towns are sometimes referred to as "Randstad" (Rim City) because of their dispersion along an imaginary ring or band (see Map 1).

Formerly the individual towns and their immediate surroundings used to function as fairly autonomous labour-market areas. The developments just described have led to such an extension of the spheres of influence of the individual centres that the labour markets have come to overlap. Owing to increased car ownership and the resulting extended range of a large part of the professional population, the towns came to lie within one another's commuting range.

The rural surroundings of the towns--especially the central open area and some spillover areas--became attractive as residential areas, not only because in these areas new houses satisfying higher quality requirements could be built, but also because they offered good possibilities of commuting to several employment centres. The conclusion is that the polynodal structure of the West of the Netherlands facilitates a spread of houses and workplaces which, potentially at any rate, entails very large traffic flows and numerous inter-crossing relations. Since the late 1950s the national government has expressed in various memoranda its view of the spatial development of the country and, in particular, the western part. An important element of these documents is the idea that the process described in the previous section must not be allowed to continue unchecked, but has to be controlled in order to prevent urban centres from falling into decline and allow rural areas to preserve their agricultural and cultural-historical values. To lessen the pressure on the towns and to check unwanted commuter flows, policy has been directed towards providing quantitatively and qualitatively adequate housing close to the Randstad. To that end a number of growth centres were designated, and a very large proportion of all new housing is now being

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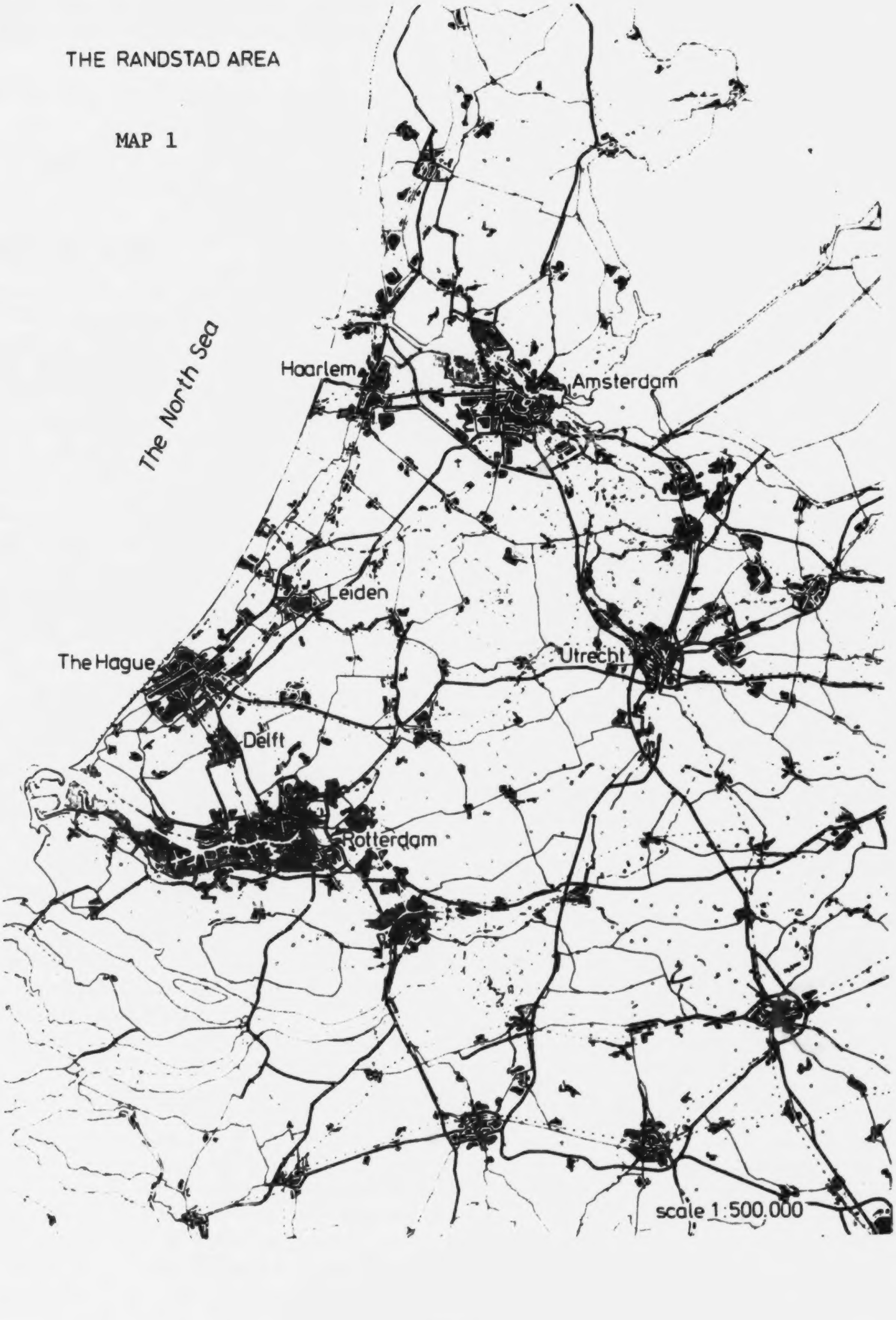
THE RANDSTAD AREA

MAP 1


The North Sea
Haarlem
Amsterdam
Leiden
The Hague
Utrecht
Delft
Rotterdam
scale 1:500,000

realised there. Hopefully, the efforts to keep people and activities in, or at any rate as close as possible to the towns, will shorten the commuting distances and enable a relatively large proportion of commuters to cover these distances by public transport, on foot, or on bicycles. Thus, preference has been shown for a structure of separate urban regions which should function as autonomously as possible, rather than for a Randstad structured as one single large urban region.

Uncertainties and Need for Research

The realisation of the policy outlined in the previous section is fraught with uncertainty. First, one does not know whether the desired spatial structure can be accomplished and second, one does not know whether, if accomplished, it will indeed bring about the desired effects on mobility. More specifically the following uncertain factors can be mentioned.

- The national government wants to restrict the commuter flows from the spillover areas to the West, by having more houses built in the west itself, and by stimulating the creation of employment in those areas. It is questionable if such a policy will indeed significantly check the growth of commuting given migration behaviour and the distance sensitivity of commuting.

- The policy is directed towards the concentration of living and working within a number of separate urban regions; the goal to strive for is an equilibrium between living and working in each urban region, so that essentially everybody can find a job within the region where they live, or locate a home near their place of employment. One wonders whether a home-work equilibrium in an urban area (if that can be achieved at all) will indeed be a sufficient condition to reduce to a minimum the commuter flows crossing the boundaries of the area.

- Preference has been pronounced for concentrating activities which have outgrown the towns in a number of growth centres. In these municipalities large quantities of houses are being built with financial support from the national government, which also finances the infrastructural provisions the "new towns" require. The government hopes that newly created employment, or industries arriving from the old towns, would settle in these growth centres; but, in practice that is not yet happening everywhere nor at the desired rate. A study of the pattern of relations induced by these developments is recommended to find out what would be the best locations for additional growth centres or other large new concentrations of living and working.

- How the migration of families and the location behaviour of industries and offices are going to develop and how that will affect the commuter flows will greatly depend on the development of the transport infrastructure. Apart from checking the growth of commuting, government policy aims at having public transport and slow traffic provide most of the home-to-work commuting moves. The location of houses and workplaces in respect to infrastructure (roads, railroads, metropolitan railways, tramway and bus lines) and the layout of road and public-transport networks within and among the urban regions--especially the distances between them--are important aspects in this connection. Both the volume of commuting and modal split are also governed by the socioeconomic characteristics of the population in the various residential areas (towns, suburbs, growth centres, rural areas), and the kinds of employment offered in the various employment centres (central towns, sub-centres within the towns, growth centres, rural towns).

To gain a better insight into all this, an inquiry into the moving of families, the moves of professionals to other jobs, and commuting, and their mutual relationships is necessary.

The description and explanation of the relationships should reveal whether the government has a chance, through judicious planning of the locations of working and living and making the required infrastructure available, to achieve certain objectives. If policy objectives are to be attained, the government has to consider the preferences of the various actors in society (families, industries, local authorities); indeed, for plans to be socially feasible, government objectives have to be in accordance with those preferences.

To discover the preferences in society and appreciate their consequences, we have to find out first and foremost how changes in the spatial patterns of living, working, and commuting are connected. Such changes are determined, apart from government policy and industrial location behaviour, by the way families behave in respect to house-moving and job changing.

A few years ago the Projectbureau Integral Transport Studies started a program of research to study those topics, the implementation of which was entrusted to the Netherlands Economic Institute. For this new approach the following principles were formulated:

- Collection of consistent data on living and working addresses of households and relevant characteristics of commuter trips of their working members, both at the time of observation and at one or more earlier times; thus, any changes occurring in each of the three aspects during a certain period could be registered.

- Formulating and testing hypotheses on the relations between changes, finding out when and to what extent they play a role. The expectation is that a strong connection will be found wherever commuting and a change in residence or workplace are substitutes, which in the polynodal structure of the western part of the Netherlands will happen in various ways.

- Designing and applying methods to indicate, on the basis of the knowledge acquired, how the process may develop in the future, given government planned residential and employment locations and transport infrastructure.

- Carrying out the research in stages, with interim results, is already useful to government planners. This last requirement has been added because of the unfavourable experiences with previous large model studies which, as the present study is expected to, went on for a long time.

On these principles, a step-by-step approach was adopted, the first step being a descriptive investigation to acquire an idea of the volume and nature of the phenomena to be studied in the Randstad and adjoining territories. Next, the behaviour of a sample of households during a period of five years was investigated in detail for the purpose of explaining the connection between migration, work change, and commuting. Recently a need for forecasts became apparent. A preliminary application was made based upon the explanatory part of the investigation with the objective of using the knowledge to develop new forecasting methods. Simple allocation models were applied and refined using the insights gained in the descriptive part.

Descriptive Analysis

The objective of the first research step was to acquire a good picture of the nature and volume of the phenomenon to be studied. To that end an "accounting" diagram was drawn up from which house-moving and work-changes flows between the zones of a region in an observation period could be read in a straightforward manner. An example of such a relocation diagram for two zones (1 and 2) is represented in Table 1.

The matrix borders refer to quantities valid at a point in time: row totals at time t-1, column totals at time t; these quantities have two indexes, the former indicating the residential zone, the latter the work zone. (If an individual was not working at one of the two points in time, that has been indicated by index 0.) The row and column totals represent the commuter flows between the two zones (including the interzonal commuter traffic) at both points in time. The interior part of the matrix contains period quantities showing how the situation at time t-1 passes into the situation at time t. Most elements have four subindexes, the former two referring to the individuals' residential and employment situation at time t-1, the latter two indicating the situation at time t. The elements give the following information:

- the volume of the migration relations with the outside area (emigration and immigration);
- natural population growth and deaths per zone of the study area (here taken together with emigration and immigration [u and i, respectively];
- people entering and leaving the labour process, by zone ($x_{io,kl}$ and $x_{ij,ko}$, respectively);
- interzonal migration;
- interzonal work change.

TABLE 1: AN ACCOUNTING DIAGRAM FOR A TWO-REGION STUDY AREA

to time t from time t-1		residential region	1	2	1	1	2	2	emigration or deaths	total at time t-1
		occupational region	did not work (0)		1	2	1	2		
res. region	occup-region									
1	did not work (0)		$x^{\Delta t}_{10,10}$	$x^{\Delta t}_{10,20}$	$x^{\Delta t}_{10,11}$	$x^{\Delta t}_{10,12}$	$x^{\Delta t}_{10,21}$	$x^{\Delta t}_{10,22}$	$u^{\Delta t}_{10}$	x^{t-1}_{10}
2			$x^{\Delta t}_{20,10}$	$x^{\Delta t}_{20,20}$	$x^{\Delta t}_{20,11}$	$x^{\Delta t}_{20,12}$	$x^{\Delta t}_{20,21}$	$x^{\Delta t}_{20,22}$	$u^{\Delta t}_{20}$	x^{t-1}_{20}
1	1		$x^{\Delta t}_{11,10}$	$x^{\Delta t}_{11,20}$	$x^{\Delta t}_{11,11}$	$x^{\Delta t}_{11,12}$	$x^{\Delta t}_{11,21}$	$x^{\Delta t}_{11,22}$	$u^{\Delta t}_{11}$	x^{t-1}_{11}
1	2		$x^{\Delta t}_{12,10}$	$x^{\Delta t}_{12,20}$	$x^{\Delta t}_{12,11}$	$x^{\Delta t}_{12,12}$	$x^{\Delta t}_{12,21}$	$x^{\Delta t}_{12,22}$	$u^{\Delta t}_{12}$	x^{t-1}_{12}
2	1		$x^{\Delta t}_{21,10}$	$x^{\Delta t}_{21,20}$	$x^{\Delta t}_{21,11}$	$x^{\Delta t}_{21,12}$	$x^{\Delta t}_{21,21}$	$x^{\Delta t}_{21,22}$	$u^{\Delta t}_{21}$	x^{t-1}_{21}
2	2		$x^{\Delta t}_{22,10}$	$x^{\Delta t}_{22,20}$	$x^{\Delta t}_{22,11}$	$x^{\Delta t}_{22,12}$	$x^{\Delta t}_{22,21}$	$x^{\Delta t}_{22,22}$	$u^{\Delta t}_{22}$	x^{t-1}_{22}
immigration or natural growth			$i^{\Delta t}_{10}$	$i^{\Delta t}_{20}$	$i^{\Delta t}_{11}$	$i^{\Delta t}_{12}$	$i^{\Delta t}_{21}$	$i^{\Delta t}_{22}$	p.m.	i
total at time t			x^{t}_{10}	x^{t}_{20}	x^{t}_{11}	x^{t}_{12}	x^{t}_{21}	x^{t}_{22}	u	x^{t-1} x^{t}

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For a first impression of the relation between the spread of residential and work activities among zones in the West of the Netherlands, and of the relation between migration, work-change, and commuter flows in these zones, we have tried to quantify relocation matrices of the type (Verster e.a. 1981). To that end we could use the basic material of the Labour Force Survey Sample (AKT) held every two years by the Netherlands Central Bureau of Statistics (CBS) among 2% of all households. These surveys contain not only information about the housing and work situation of respondents on the survey date, but also about that situation one year before. We have made use of the 1975 and 1977 countings for about 100,000 respondents, which the CBS had raised by suitable factors so as to reconstruct the total population.

The analysis concentrated on those who had been gainfully occupied during the whole period, and more in particular on those among them who had moved house and/or changed jobs. We shall illustrate the analysis of this information with an example in which the basic material has been spatially aggregated by three types of zone:

1. the four largest towns of the area (Amsterdam, Rotterdam, The Hague and Utrecht);

2. the urban area around these towns (where the national government would prefer to see concentrated a large portion of the growth of living and working activities);

3. the rest of the study area (rural area and peripheral towns). The whole study area covers an area of more than 20,000 square km (more than 8,000 square miles), and counted 11.3 million inhabitants on January 1, 1976.

The distribution of the working population (about 3.3 million people) by region of residence and employment at the two benchmark dates (Table 2) shows that a shift in the residential spread of working people had occurred that does not fully agree with policy preferences.

The shifts were due, on the one hand, to changes in supply of houses and workplaces, on the other, to the behaviour of workers. If we look upon the three regions as a closed area, so that external migration and commuting relations may be neglected, the shifts can be reduced to entries into and departures from the labour market for one thing and interregional living and working relocation for another.

The commuting pattern emerging from the spread in 1975 and 1977 is represented in Table 3, from which we see that interregional commuter traffic increased from 501,500 in 1975 to 558,400 in 1977, an increase of 11% in two years' time. Part of the increase is due to the (slight) increase in employment, but the share of commuters in the total of all workers also increased greatly: from 15.1% in 1975 to 16.5% in 1977.

TABLE 2

SPREAD OF THE WORKING POPULATION AT THE BEGINNING OF THE YEARS 1975 AND 1977, BY REGION OF RESIDENTIAL AND EMPLOYMENT ORIGIN (%)

Region	1975		1977	
	Living	Working	Living	Working
1	22.4	29.0	21.1	28.4
2	23.8	21.0	24.4	21.6
3	53.8	50.0	54.5	50.0
Total	100.0	100.0	100.0	100.0
	= 3,329,400		= 3,373,400	

With the help of a relocation matrix of the type described in Table 1, changes in commuter flows by relocation motive can now be distinguished. We shall confine ourselves here to the group of workers who remained occupied during the period 1975-1977 (those who did not start or stop working), and moreover went to another municipality for living and/or working. Table 4 pictures their behaviour. From this table one can deduce directly--dependent on the way of aggregation over the $3^4 = 81$ cells--the migration and job-changes matrices for this period as well as the commuter matrices at the beginning and end of the period.

TABLE 3

INTERREGIONAL COMMUTER FLOWS ALONG THREE REGIONS IN 1975 AND 1977 (x 1,000)

to	1975				1977			
from	1	2	3	TOTAL	1	2	3	TOTAL
Region 1	661.8	60.9	22.6	745.4	620.9	64.4	25.3	710.6
Region 2	187.7	566.1	39.5	793.3	204.1	576.8	43.1	824.0
Region 3	117.5	73.3	1,599.9	1,790.7	134.0	87.5	1,617.3	1,838.8
Working	967.1	700.3	1,662.0	3,329.4	959.0	728.7	1,685.7	3,373.4

TABLE 4: RELOCATION MATRIX OF LIVING AND WORKING AMONG THREE REGIONS FOR INTER-MUNICIPAL MOVERS DURING THE PERIOD 1975-1977 (x 1,000)

to time t from time t-1		region of residence	1	1	1	2	2	2	3	3	3	commuting at time t-1
		region of employment	1	2	3	1	2	3	1	2	3	
region of residence	region of employment											
1	1		6.7	6.9	2.9	18.0	2.3	0.0	12.0	0.2	4.8	53.8
1	2		6.2	1.2	0.7	0.2	5.7	0.0	0.0	1.3	0.3	15.6
1	3		1.8	0.4	0.3	0.0	0.0	0.6	0.1	0.1	4.1	7.4
2	1		6.4	0.1	0.0	7.6	9.4	1.4	3.4	0.1	0.8	29.2
2	2		1.8	2.5	0.1	10.8	43.1	5.8	0.3	7.2	7.4	79.0
2	3		0.0	0.1	0.2	0.8	4.2	1.2	0.1	0.1	4.4	11.1
3	1		3.7	0.0	0.0	2.6	0.4	0.0	5.8	2.3	6.3	21.1
3	2		0.0	0.2	0.0	0.0	5.8	0.1	1.0	5.6	5.1	17.8
3	3		2.0	0.2	1.2	1.0	3.7	2.7	7.9	8.6	156.6	183.9
Commuting at time t			28.6	11.6	5.4	41.0	74.6	11.8	30.6	25.5	189.8	418.9

The data from AKT 1975 refer to the year 1974, those from AKT 1977 to the year 1976; they have been summated here and interpreted for the purpose of the example as a description of the two-year period 1975-1976. Moreover, the data material has been corrected as well as possible for lags and leads. An observation period of only one year implies that there are relatively many respondents who changed their regions of living and working but of whom only one relocation has been observed. The material presented above enables us next to analyse closer the shifts in the commuter pattern and to examine:

1. to what extent commuter shifts between 1975 and 1977 can be attributed to (a) the effect of entering and leaving the labour market, and the effect of residential and employment relocation,
   (b) progressive asymmetry in the regional distribution of living and working activities;

2. to what extent commuting shifts caused by the group of inter-municipal movers are due to interregional migration, employment change, or a combination of the two.

From Tables 3 and 4, three matrices can be deduced representing the changes that occurred in the nine commuter flows between 1975 and 1977. Out of the total additional 56,900 moves among the three regions, 33,700 can be ascribed to the net effect of starters and stoppers, and 23,700 to interregional residential and/or employment relocation of the remaining movers. The latter group is mainly characterised by the dispersion of living from the large towns (region 1) to region 3 and (to a lesser extent) to region 2. The net effect of starters and stoppers is expressed primarily in the growth of the number of workers in regions 2 and 3.

On the fiction of a completely homogeneous labour and housing market, one can split commuting into two parts: one part inevitably following from the fact that the professional population is distributed in different ways among living and working regions at a certain moment in time (asymmetry[1]) and another part that could be defined as "not strictly necessary" commuting. From Table 3, the asymmetry in the spread of living and working activities amounted to 221,700 persons in 1975 and 248,200 in 1977. So asymmetry increased by 26,700 moves, while total commuting increased by 56,900 moves, which means that nearly half the rise in commuting can be reduced to the redistribution of aggregates of living and working opportunities among the regions. Table 5 shows how the increase in asymmetry and commuting is divided among starters/stoppers and other movers.

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1) If P_{ij} = the number of workers living in region i and working in region j, the asymmetry is defined as

$$a = 1/2 \sum_i \left| \sum_j (P_{ji} - P_{ij}) \right|$$

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TABLE 5

INCREASE IN INTERREGIONAL COMMUTING THROUGH RELOCATION AND STARTERS/STOPPERS, DIVIDED INTO ASYMMETRY AND OTHER COMMUTING, 1975-1977 (x 1,000)

Increase in	Effect of		All workers
	migration and job changing	starting and stopping	
asymmetry	+ 27.3	- 0.6	+ 26.7
other commuting	- 3.6	+ 33.8	+ 30.2
total commuting	+ 23.7	+ 33.2	+ 56.9

The increased commuting of migrants and job changers is almost entirely due to an asymmetric redistribution among residential and employment regions. As far as other factors are at work, they even contributed to a more efficient location of living in relation to working, and thus to a drop (of 3,600) in the number of moves. The net effect of entering and leaving the labour market is quite the reverse: starters take up residence and jobs in the regions where the stoppers used to live and work; however, they distribute themselves far "less efficiently" among the living and working regions.

The number of persons living and working in the large towns (region 1) dropped in two years' time by 41,000. The larger part (25,200) of the decrease was due to relocation. Table 6 shows the gross flows producing this net commuting effect, divided into residential migration, employment change, and combination of the two. The same has been done for incoming flows into region 1 from regions 2 and 3. Table 6 has been derived from Table 4.

The increase in the incoming commuter flows are mainly due to migrants continuing to work in their old employment region. However, looking at the total number of persons involved in the net effect (95,100) we find that only 55% of them just migrated, and that more than 40% of the 95,100 individuals were non-migrating interregional job changers. In the latter group, incoming and outgoing flows were (still) balanced. From other studies (Molle e.a. 1981), suburbanisation of industries from region 1 indeed appears to increase.

On the one hand, that makes for less incoming commuting into the large towns, on the other, for an increase in outgoing commuter moves. A similar tabulation for outgoing commuter moves from region 1 teaches us that persons who only change their jobs do indeed have a slight positive effect on outgoing commuting.

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TABLE 6

INCREASE IN SOME COMMUTER FLOWS BY MOTIVE, 1975-1977 (x 1,000)

Commuting	Interregional migration, without interregional job changing			Interregional job changing without interregional migration			Interregional migration and job changing			Total net effect
Region	out	in	net	out	in	net	out	in	net	
from 1 to 1	-30.0	+10.1	-19.9	- 9.8	+8.0	-1.8	-7.3	+3.8	-3.5	-25.2
from 2 to 1	- 9.8	+20.6	+10.8	-10.8	+11.6	+0.8	-1.0	+1.2	+0.2	+11.8
from 3 to 1	- 6.3	+15.4	+ 9.1	- 8.6	+ 8.9	+0.3	-0.4	+0.5	+0.1	+ 9.5

So much for this example of the regional analysis which can be carried out with the help of the accounting arrangement discussed before.

The study described has not only worked with various areal divisions, but also gave attention to various categories of persons: main earners, other working members of households, sex, education, profession, etc. It contained, besides the regional analysis, the study of spatial behaviour, by interaction distance and transportation mode.

Towards an Explanatory Analysis of the Relation Between House-Moving and Job-Changing

If we want to find out how the home- and job-finding efforts of households and working individuals have brought about the aggregate problems referred to earlier and how policy measures can contribute to bending behavioural tendencies in an envisaged direction, we need to understand how individual decisionmaking works. We know from many empirical studies of mobility on the housing and labour markets that the majority of actual movers seem to have decided on moving without heed to the commuter distance they have to cover, either to another house without having in mind or having realised a change of jobs, or to another job without contemplating or having accomplished a house moving. Most moves are short-distance ones anyway.

On the other hand we know that 6% of all relocaters in the western part of the Netherlands have stated as the main reasons for their latest relocation either a planned change in home or work location or dissatisfaction with commuting distance they or their partners had to travel; twice as many mentioned these factors as one of their reasons. We may trust that many more people who considered moving but finally decided not to, had taken the commuting distance into account.

Presumably, then, the number of cases in which the decision to move house is related to a change of jobs, or that to change jobs to a house move, in the West of the Netherlands is larger than would appear from the figures; consequently, the significance of changes in interregional commuting and dispersion phenomena tends to be underestimated. There is every reason, therefore, to plead ample attention to such a relation as we set out to analyse how decisions on house moves and job changes are made. The plea is supported by the research results of others (Brown 1975).

Studies of mobility on the housing and labour markets tend to split the decisionmaking process preceding an actual change analytically into two decisions (Rossi 1955, Moore 1972, Morrison 1973). First comes the decision to look, actively or not, for another house or another job. A change in the household's characteristics and those of its working members, a mutation in the residential situation, or a development in the general conditions of the housing market may trigger off the decisionmakers's active search. Once a potential new dwelling has been found, its "place utility" (Wolpert 1965) will be compared to that of the present location, and a decision is made: to stay or to move. If the decisionmaking on living is to be related to that on working, two decisions can once more be distinguished. The first decision is to become, or not to become, active on the housing market and/or the labour market. When a potential new home-and-work combination has been spotted, the advantages of the old and new combinations will be weighed. In this case, the place utility of the alternative combinations can be split into three separate utility components: the (dis)satisfaction derived from:

- the residential location and environment;
- the work location;
- the daily home-to-work trip. The total utility of the new combination in respect to the old one determines the chance of actual transfer.

Not all moves are undertaken voluntarily, however. Sometimes people are forced to leave their houses; sometimes people lose their jobs. A decision may also concern the question whether to start or stop working (a question especially relevant if there is more than one worker in a household); the formation, disintegration or split-up of households is another factor to take into account.

Decisionmakers whose behaviour is the result of an explicit weighing of the above three components will be found mainly among:

- long distance commuters (divided into temporary commuters whose residential and occupational moves have not coincided, and permanent long-distance commuters);
- people who, within the western part of the Netherlands, have relocated residentially and professionally, and would have become long-distance commuters if only one change had taken place;

- persons who stopped working after a house move and would have had a long distance to travel if they had continued to work at the former workplace;

- workers suffering from long daily traffic delays;

- workers who have shortened their commuting time by changing their mode of transportation.

A stratified survey has been carried out in the northern part of the area defined above (with Amsterdam as its centre) so as to get to know in detail how these groups of decisionmakers behave spatially, and to examine how their behaviour can be explained from the development of other variables.

Early during the interview a relocation form was filled out, with quarterly data through a period of five years: the residential address, the work address, and the principal means of transportation relating to each address combination for the main breadwinner and the second worker (if any). Next, the composition of the household was considered, the residential characteristics, the work situation of the first and second workers, the mode of transport, and certain constraints (residential costs, income, work hours, car ownership, etc.). Ample attention was given to changes in these characteristics during the retrospective observation period. The survey was held in 1980 and the tape with the unprocessed data was delivered early in 1981. The investigation will be carried out in three stages. First, the relocation forms will be processed, providing us with an impression of the relation between relocation and modal choice through a medium-long period.

In the second stage there follows an analysis of the spatial behaviour of those groups of respondents who presumably have weighed the three utility components. Their behaviour is compared with that of the other respondents, and its determination by observable constraints judged (demolition of houses, policy of housing allocation, restrictions on the sale of housing, lay-off by previous employer, etc.). At this stage individual choice models (logit, probit) will also be applied. To the analogy of the decisionmaking dichotomy, the behavioural models can be divided into mover-stayer and distribution models.

This part of the analysis should also give attention to the influence of variables that to some extent can be influenced by government policy (supply and financing facilities of houses of a certain quality, improvements in public transport, travel-time contraction by measures against traffic congestion, parking policy, etc.).

During the last stage we shall examine how the information from this disaggregate analysis can be applied to policy problems on an aggregate level. Feedback to the Labour Force Survey discussed in section 3 comes to mind here. The observed characteristics of the AKT-respondents need to be completed with simulated unmeasured characteristics, to be distributed according to the simultaneous division of the two kinds of characteristics as measured by the disaggregate analysis.

Experiment with a "Double-Allocation Model" For Living and Working

The main purpose of the investigation reported on here is to explain spatial behaviour by a disaggregate analysis. But could information of the kind described in Table 1 also serve for immediate forecasts, thus fulfilling a need government planners were feeling while working on the structural outline for urbanisation? To answer that question, an experiment was undertaken to achieve an interaction model describing in an integrated way interregional flows of home as well as workplace changes.

Table 1 can be rewritten in matrix form:

$$\underline{x}^{t} = X\,\underline{x}^{t-1}$$

in which the elements of X are quotients of the matrix elements $x_{ij,kl}$ and the corresponding row totals. Matrix X consists of nine submatrices. One can interpret X as a matrix of constant transition probabilities, but in that case the system is reduced to a very rigid Markov-process. One can also go one step further, however, splitting matrix X into a mover matrix M and a stayer matrix (I-M), and next premultiply M by a distribution matrix D. On those assumptions, the following expression applies to the situation at point in time n:

$$\underline{x}^{n} = \prod_{k=n}^{1} \left\{ D^{k}M + (I-M) \right\} \underline{x}^{t-1}$$

The next step is to try and relate the elements of D^k to some independent variables referring to point in time k, for instance: migration and work-change distances, houses and jobs coming available, and commuting distances.

Our experiment has been of a limited scope, being restricted to the application of a matrix for 19 years.

To estimate how to divide the persons changing from their home-and-work combination at time t-1 to the combination at time t, entropy maximalisation under constraints can be applied to the analogy of the utility components distinguished in Section 4, three system-wide net cost constraints can be assumed, viz. a removal-cost constraint, a job changing-cost constraint, and a constraint reflecting the change in commuting costs. The traffic flows observed at time t-1 moreover constitute the origin constraint.

If we left it at that, we should have an analogy of the single constrained migration model. To represent the limited possibility of extending the housing supply and the supply of employment during an observation period, two destination constraints can be added, namely, a residential destination constraint and an occupational destination constraint.

The first estimation results, obtained with the diagonal-variable metric method (den Broeder, 1980) are promising. If the further exercises are successful too, the results will form a welcome addition to conventional interaction models. An interesting aspect of this double allocation model is indeed that by different ways of aggregation, four mutually consistent interaction matrices are acquired: the migration-distribution matrix, the work-change distribution matrix, and two matrices representing the structure of commuter trips at time t-1 and time t, respectively.

Summary and Conclusions

In the preceding chapters we reviewed our studies on the relationships between land use, residence and workplace mobility, and commuting. As the work is still under way, it is far too early now to make a final assessment of the results. We only can provide some tentative conclusions.

We have seen that the subject and the character of the study have grown out of the specific needs of government planners. These needs arose because of uncertainties about the implementation of the policy that has been defined by the national government. This policy is directed towards checking the growth of commuting by car over long distances. Therefore, concentration of living and working within a number of separate urban regions is preferred, and the use of public transport and slow modes encouraged (section 1).

In order to let the study comply with the planners' needs for information, we decided to try a new approach for which four principles were formulated (section 2). We end this paper by confronting the current state of affairs with those four principles.

- Data collection - The requirement that consistent data should be collected on living and working addresses of households and on commuter trips has been met. The data from the Labour Force Sample Survey (AKT's) 1975 and 1977 appeared to be useful for descriptive analysis, subject to certain margins of error. More detailed information has been collected by holding an extensive household survey of our own. The Netherlands Central Bureau of Statistics carries out the AKT's every two years. It is our intention to analyse future AKT data along the same lines as was described in section 3. This means that the study has provided planners and policymakers with a useful monitoring device.

- Explanatory analysis - Testing of hypotheses on the behaviour of individual households and employed persons with regard to their changes of residence and workplace still has to be performed. The data that are needed have recently become available and in section 4 we described the way we should proceed.

- Evaluation of policy alternatives - Instruments still have to be developed, making use of the results of the explanatory part of the study. At present there are only rather vague ideas about how the models will look. Perhaps we will fall back to a certain extent on techniques that are already existing, but amending them in such a way that a less static framework is obtained. A link with transport models (also amended to concentrate on changes) would be very useful. The chance of succeeding for such an approach seems to be good, given the experience with the simple double allocation model (section 5).

- Step-by-step approach - This approach has been very successful as results from the descriptive stage of the study proved to be directly useful. In addition, the descriptive analyses provided indications that were useful for the design of the household survey. The experiment with the double allocation model aims at providing information just when it is needed. Indeed, a regular supply of interim results is an important condition for a lasting interest in a study on the side of policymakers.

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DEVELOPMENT EXPECTATIONS AND EXPERIENCES OF MAJOR PUBLIC TRANSPORTATION INVESTMENTS

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Abstract

This paper examines the extent to which applications of microeconomic theory can be useful in predicting the land use/urban development impacts of major urban transport investments in the light of actual experience in Philadelphia, Toronto, and San Francisco. It concludes that the results predicted by partial equilibrium economics may be distorted or reversed by factors exogenous to the models, such as levels of accessibility in other areas, the planning climate, and the business climate. Finally, it cautions against making large urban transport investments in cases where a specific urban development outcome is essential to the success of the project.

Introduction

The objective of this paper is threefold: first, to summarize some of the more important development/urban form expectations associated with a major change in the supply of urban public transportation; second, to assess the extent to which such expectations have or have not been realized in selected North American cities; third, to draw conclusions for the general types of performance measures that would appear most useful in the analysis of public transportation and development/urban form.

The Development Expectations of Economic Theory

The problem with which we are faced, namely, to predict the magnitude and nature of urban land use changes associated with changes in the transportation system supply, is not well treated in conventional literature. For various reasons this kind of problem falls outside the three principal conventional approaches: those of the urban spatial theories, the standard urban transportation land use study, and cost-benefit analysis of particular schemes. Each approach has some appropriate features, but no author has selected and combined them in a manner totally suitable for this purpose. There is, however, what might be called a "conventional economic wisdom" derived from applied price theory. This considers the impacts of given price changes in a partial equilibrium framework. The price change of interest here is that induced by investment in the supply of transportation. To simplify the discussion, we limit ourselves in this paper to changes in the supply of public transportation.

Consider what the application of microeconomic analysis might be were it to address this problem directly. It must basically consider the behaviour of both firms and individuals when faced with changes in accessibility occasioned by a new rail or bus facility. In so doing, it must expect to distinguish differing effects with respect to different locations along a corridor, that is, at the central business district (CBD) end, at the periphery of the urban area, at intervening locations with connections to the wider network and at other intervening locations.

The first expectation which arises, then, is that as a result of these relative accessibility shifts (price reductions), development will be attracted to the areas served by the new facility (that is, the demand for land/location would increase). Potentially, the effects upon specific locations along the line are more complex. In terms of a single radial rail line, central area locations are affected least by these accessibility changes--they already enjoy a central position. The peripheral locations are affected most because the existing network was at its most sparse there before the introduction of the new facility. The intermediate locations fall in between the central and peripheral locations in terms of accessibility shifts.

Second, there is the corridor rent gradient which existed prior to the introduction of the new facility, which will reflect distance from the CBD. Existing land use densities will fall along the gradient, and rents will be ranked accordingly.

The third consideration is the effect of agglomeration--the attraction of established activity--on new development. In general, this will coincide in its effect on location rank order with that of the rent gradient.

We can now address the question: At which locations does economic analysis predict urban development will occur along the new/improved line? First, a distinction must be made between the change facing households and that facing firms.

Looking first at the changes with respect to residential development, we may expect the following kinds of effects. Two inducements are set for:

1. households to move to the newly convenient corridor, and
2. households already in the corridor to either move closer to their work (for example, to accept higher rents) or to consume more residential space by moving further away.

Because the corridor is assumed to be small, relative to the metropolitan area as a whole, more households are likely to move into the corridor than move along or away from it. In terms of the development of the above locations and their hinterlands, we would expect the peripheral locations to be most affected because they combine the favourable circumstances of the largest change in accessibility together with the lowest initial rent. Some outward limit to this effect must occur. For example, outside, say, one hour's door-to-door commuting time, the impact will be rapidly lost. The central area locations, which have the lowest accessibility change plus the highest initial rent, stand at the opposite end of the spectrum. The remaining locational types take intermediate positions.

With respect to the accessibility changes from the point of view of the firm, it is clear that locations along the line can now accumulate labour from corridor/hinterland locations at a lower cost than was previously the case. Moreover, the transport improvement itself extends the potential locational advantages of the CBD outwards along the line. The average costs of assembling labour increases with distance from the CBD, given the existing distribution of employment; but, on the other hand, existing rents also fall with distance. The outward attraction for firms along the route will be affected by agglomeration economies. This confines the more likely developments to more central locations, particularly the inner intermediate locations for which existing rents are likely to be lower and access gains high. Peripheral locations are less likely to attract employment-oriented developments.

In terms of the type of development attracted to these locations, the expectations based on conventional analysis are clear. Because the accessibility change is confined to the movement of people and not goods, the expectation is that land conversion will be towards people-intensive uses. Firms with people-intensive market operations, that is, stores or certain other kinds of commercial activities such as offices will be favoured, as will those with high labour costs relative to other inputs.

It should be noted that these predictions represent only the results of a broadly conceived "once-and-for-all" change in accessibility costs facing firms and households. Conventional economic wisdom warns against over-emphasizing the importance of such changes in the economic development of urban areas. More important than shifts along given demand and supply curves, with which we are essentially concerned, are the shifts in those curves. The long-term shifts in locational patterns, as influenced by technological change in firms' demand for space, and shifts in household incomes and tastes towards more consumption of residential space would be considered by most urban economists as being far more significant than the "once-and-for-all" changes that might be induced by a major transportation investment.

Thus, when considering such issues as the impact on downtown activity, the attractiveness of the CBD relative to the suburbs for economic activity, or indeed the competitiveness to the metropolitan area itself with other urban areas, most analysts would tend to rate influences such as changes in transport as being of lesser significance.

Even on narrower issues, such as the impact on auto use and, by extension, on congestion in corridors, the conventional wisdom is skeptical. A new public transport investment simply does not bring about sufficient change in accessibility (for example, generalized cost of travel) to make much difference in the context of general urban trends in auto use, shifting work places, etc. However, there is an emerging issue here, namely, the future price of gasoline and the implications of this on the relative change in accessibility that could be offered by major investment in transit.

Summary

In sum, conventional economic analysis can address the overall impact on and likely developments along a major corridor and set the framework for a discussion of the empirical evidence. The discussion would, of course, be imcomplete without a comment on the other factors which could, in practice, result in modifications to or deviations from the predictions of urban development change based on conventional economic theory. These include factors such as neighbourhood resistance to development, irrespective of the creation of favourable economic conditions. Other factors which are likely to disturb or greatly distort the interpretations of conventional economic theory include issues of land availability, land ownership, land assembly difficulties, and the regulation of land use through zoning.

Given a knowledge of these other factors, the anticipated development effects of major public transport investments will depend principally upon the scale of the accessibility change that is introduced. Unless there is a substantial change in accessibility, there is unlikely to be any measurable development impact. Accessibility change, therefore, is a critical but often underestimated indicator of the scale and nature of urban development changes associated with transportation investment.

The theory on which the development expectations of major investments in transportation are based relates to the cost changes facing firms and households, measured in terms of both the monetary and time inputs of travel. A prospective gain in time between two areas can be reinforced, modified, or even cancelled if the prospective price of travel is low or high relative to the pre-existing options.

Systematic differences in the characteristics of residents and firms across the urban areas can modify even this impact. Cities vary in terms of the proportion of firms having characteristics more affected by changes in accessibility, for example, labour intensiveness, than by other factors such as economies of scale, etc. Similarly, cities will vary in the preferences of their inhabitants with respect to density. Such factors will also affect the observed scale of development change.

It must also be observed that the most important economic forces concern the changes affecting the metropolitan area as a whole. Hence, it is necessary to compare effects along the line or adjacent to it with changes in other areas within the city, with these other areas representing control or baseline observations.

The economic theory concerning accessibility offers little insight into the timing of development impacts. It merely seeks the final effect. The actual timing of development is likely to reflect such influences as peaks and troughs in the building cycle of the metropolitan area as a whole.

Observed development will also be affected by speculation in land, in the sense that attempts to realise development potential may bear on the timing, type, and scale of building, either by facilitating the assembly of parcels of land for building or, if the expectations are for further gain, holding back construction. In general, the larger the difference between the gain in costs represented by the accessibility of land, the greater the scope for speculative activity.

Overall, it must be accepted that the effects of large urban transport investments are likely to be influenced more by variables that are exogenous to economic models than by those that are endogenous. In the next section we examine the empirical evidence on changes resulting from major transport investments in an attempt to determine whether this presumption is borne out by the available evidence.

The Development Experiences of Selected North American Cities

In this section we summarize the underlying development trends prevailing in three metropolitan areas for which some historical evidence of the urban development impacts associated with large-scale public transport (principally rapid rail) investment is available: the San Francisco Bay Area, Toronto, and Philadelphia. We have selected rapid rail examples because these are likely to make a greater impact on the radial accessibility surface and level of development. We summarize the general nature of the development impacts experienced along the major corridors and comment on the timing of the observed impacts.

Historical Development Trends

Population Trends

All three metropolitan areas have experienced steady growth throughout the postwar period and a strong suburbanisation trend. In Toronto, for example, the metropolitan area population increased by 57% over the period 1951-1971, while the population share of the central area fell from 63% in 1951 to 34% in 1971.

Employment Trends

The trends in employment are similar in all three metropolitan areas--a progressive increase in regional employment over time, combined with major locations and structural shifts. In the Toronto metropolitan area, employment increased by 46% over the period 1956-1970, while the city [illegible] f experienced a declining share of regional employment, falling from 74% to 51% over the same period.

Similar changes in total employment can be observed in Philadelphia, with total regional employment growing at 2.2% per annum between 1959-1970, while the city's share fell from 60% in 1960 to 49% in 1970 and 31% in 1967, a dramatic decline.

The similarities in trends across the metropolitan areas remain when one examines the structural changes in employment. In each case there has been a sharp decline in manufacturing jobs and a relative drop in retail employment. Service employment has grown markedly in all three cases, helping to offset the decline in other sectors.

The Housing Market

The overall trends in household size are similar in all three metropolitan areas. Each area has experienced a significant decline in household size and an increase in numbers of households. This has led to a great rise in demand for small units, notably multiple family dwellings, in all areas.

The supply side response to this trend in demand is interesting in that the Bay Area situation differs significantly from the other urban areas. While the rates of new additions to the existing apartment dwelling stock have fallen in the Bay Area, they have increased in the other areas--by 80% in Toronto over the period 1951-1971 and by 100% in Philadelphia-Camden County over the period 1960-1970.

All three metropolitan areas exhibit similar characteristics in terms of heterogeneity of population and locational concentration of low-income groups.

While these three metropolitan areas have many common development attributes in terms of the suburbanisation of population and employment and changes in the regional structure of employment, there are also important variations. These variations relate particularly to the housing market and the significantly lower (and in relative terms reducing) share of multi-family accommodation in the Bay Area. This stands in contrast to the market trends in the other metropolitan areas. There are also differences between the densities of single-family housing across the three areas, with Bay Area single-family densities being relatively low. Both of these factors have significant implications for the development potential of major transportation investment.

Transportation Characteristics

Major differences emerge between the areas with respect to the traditional role of transit. Toronto, for example, has a long history of subway and surface transit usage, including its famous streetcars. In

Philadelphia, the commuter railroads (13 in number) have long provided a "transit-commuting" service for CBD workers. In contrast, the Bay Area has less of a tradition of commuter rail and conventional transit usage.

Even more noticeable is the difference in mobility offered by car travel in the Bay Area as compared to the other urban areas (for example, as measured by average speed), particularly with respect to CBD-related travel. Unquestionably, the mobility offered by the car is highest in the Bay Area. In the case of Toronto, it is significant that, despite the high level of auto ownership (one car to every three inhabitants), the per capita use of transit is far higher than in Philadelphia or the Bay Area.

The objectives of the rapid rail improvements also differ considerably. The Toronto system was originally intended to relieve a heavily congested route to the CBD, and was subsequently extended to provide a link to the rapidly developing suburbs. The system was oriented to the CBD and towards commuter usage.

Observations on the Nature and Timing of Development Impacts Along the Major Transportation Investment Corridors

Bay Area Rapid Transit (BART)

The BART experience of residential corridor development impacts does not correspond closely with the expectations of economic theory. Part of the explanation for this undoubtedly arises because the Bay Area is geographically more complicated than the single CBD-oriented corridor contemplated by the conventional economic wisdom. To the east of the San Francisco CBD, BART splits into three lines radiating out from a subsidiary centre (Oakland) and with a conspicuous gap (the Bay), where stations that are important from a development point of view would normally be.

But there is no obvious reason why the expectations of conventional theory should not have been fulfilled in the western reaches of BART. The "failure" of station development to achieve the locational expectations which are confirmed by the experience of the other rapid rail improvements may suggest that the potential for such development is yet to be realised. Indeed, there may well be special reasons why development here has been delayed (for example, blight, deliberate down-zoning to prevent development, or the absence of a significant multi-family apartment market).

The employment-related development results also do not conform very closely to the conventional expectations. The principal variation is the scale of the relative change in employment at considerable distances from the CBD, which exceeds the expectations, although in absolute terms the change is small.

Toronto METRO

Since the early 1950s, residential development along the major Toronto rail corridors has been characterised by apartment building, including substantial high-rise residential development just outside the CBD itself. This was, in fact, stimulated by the Toronto planning authorities working in association with METRO in the face of a rapid population increase and a decline in average household size. Altogether, the pattern displayed is not unexpected, with development becoming more mixed in character as one moves out along the rail corridors from the CBD.

The major Toronto metropolitan areawide development trends showed a fluctuating but positive growth in residential and commercial activity over the period of the 1950s to mid-1970s during which the Metro was introduced. In particular, commercial activity in the CBD experienced a slow rate of growth between 1958 and 1963 relative to other locations. Since 1963 the rate of growth of the CBD's commercial sector has taken off, a point of significance to the timing of transit-related development impacts. Growth in residential dwelling units also increased over this period, from an annual growth rate of 12% in the 1950s to an average of 23% in the 1960s.

Considering now the along-the-line impacts with respect to Yonge Street in particular, the Toronto Transit Commission reports a notable time lag between the opening of the line in 1954 and the subsequent development of the air rights along its length. Twenty-two blocks were purchased along the right-of-way; 17 were built for office, retail, and residential development between 1960 and 1973.

This time lag between the start of rapid transit service and subsequent property development mirrors the general development trends in the metropolitan area noted earlier. Thus, while the potential for development was created along the line, this was not realised to any extent until the general upswing in the cycle of development activity in the early 1960s.

For other lines in Toronto, a similar correspondence is also apparent between the general development cycle and the timing of developments along the rapid transit corridors. For instance, there was no time lag between the initiation of service and the development of air rights on the Keele to Woodbine section of the East/West Line, which opened in 1966. Moreover, the development of the air rights on the suburban line extention (for example, the high-rise apartment and commercial development of Islington Station), preceded the opening of the route in 1968.

Lindenwold Line

Along the Lindenwold Line (Philadelphia) the greatest absolute increase in office floorspace has occurred in the vicinity of CBD stations. Office development has also occurred near the end of the line and at two stations which are well connected with the highway system.

Residential development has been especially notable in fast growing suburban areas at the end of the Lindenwold Line and is comparable with the Toronto end-of-line stations.

Unlike the Yonge Street Line in Toronto, the Lindenwold Line was opened in 1969 during a period of relatively strong commercial growth. Unfortunately, there is no systematic data available for the derivation of areawide trends in office, retail, or housing development. However, there is some information on office development activity in the New Jersey area, and we have some evidence--albeit very sketchy--on the scale of office floorspace stock built at suburban locations along the Lindenwold route and some pointers to the timing of its construction.

From the evidence available, it is clear that the line's suburban stations have attracted some new office floorspace, much of it during the initial three to four years of operation (1969-1972/73). The amount of new floorspace involved is, however, small; the total new office floorspace area at suburban stations is estimated to be between 180,000 and 230,000 (gross) square feet. The most floorspace attained by any one station area is in the order of 125,000 square feet over the period 1966-1975. Most of this space was concentrated at suburban stations.

In the same period, the city of Philadelphia increased its office stock by some 10 million square feet, 50% of which was added between 1960 and 1970, with the balance added between 1970 and 1974. Over the period 1960-1970, Camden County, through which the Lindenwold Line runs, increased its total office stock by some 2.5 million square feet.

In the context of the metropolitan area development cycle, the line's opening and its initial years of operation coincided with a resurgence of commercial development following a relatively depressed period. This was associated with an increase in the availability of construction finance. To the extent that is discernable from the evidence, this is reflected in the timing of such commercial development as has occurred along the line.

Thus, the greater part of the line was opened shortly before a sharp upswing in the city's office development cycle. In light of this--given the expectations on the timing of development--one might expect a greater share of the commercial development around the line's stations to have taken place during the period 1971/72 to 1975, with very much less development occurring from 1976 to the present than, in fact, appears to have been the case. To a considerable extent, this delay in the timing and scale of development at particular stations is a function of the requirement of Philadelphia's office and planning policies, which have undergone a series of changes since the mid 1960s.

Conclusions

Starting from what might be predicted on the basis of simple urban economic arguments, we have reviewed major changes in urban transportation supply as representing relatively small changes in the conditions influencing the location decisions of households and firms and urban structure. This is reflected in the development/urban structure impacts experienced by the metropolitan areas selected which do not extend to the metropolitan areawide level, even in the most favourable circumstances for an increase in the supply of public transportation.

The essential conclusions to be drawn from this discussion of the analysis of public transportation and urban form/development are as follows:

1. Along-the-Corridor Development Experiences

   Here, the expectations of conventional economic theory have been broadly fulfilled by the localized residential and economic development experiences of the Toronto and Philadelphia rail facilities, but not by BART.

   This difference could well be attributable to the urban characteristics of the Bay Area onto which BART has been superimposed. Thus, unlike the other two metropolitan areas, the Bay Area has no long-established tradition of transit usage. Moreover, unlike the other public transportation investments examined, the evidence suggests BART brought about no relative increase in accessibility in the Bay Area, being introduced in corridors having excellent existing highways and highly competitive express bus services. In addition, there is evidence to suggest that some potentially important locations along BART routes have been deliberately down-zoned, thus, precluding any transit-related development.

2. Timing of Development

   A comparison of the timing of public transportation associated development impacts relative to the commencement of a major new service suggests that a period of rapid urban commercial and residential development is virtually a prerequisite to the realisation of the development potential created by that investment.

   In the case of Toronto, for example, the first line was constructed during a somewhat depressed economic period; associated development lagged by five to six years behind the opening of the line. As the pace of building activity picked up, the lag between the construction of a new line and the associated development diminished. In the Toronto situation most analagous to that existing in the Bay Area at the commencement of BART service, development was proceeding in parallel with subway construction; the lag between subway construction and the development response was virtually non-existent. This suggests that the extent to which rail-associated development does occur is influenced by the overall metropolitan rate of economic development, and the closer the correspondence of a general upswing in general economic activity with the opening of a line, the shorter the response of related development.

3. Implications for Development Planning

Several implications for development planning follow. First, the expectation of any development occurring in response to the introduction of a major new public transportation facility is primarily dependent upon the scale of the relative accessibility change brought about by the facility itself and to the prevailing economic climate in the metropolitan area as a whole. Without both a significant increase in accessibility and a climate conducive to development, it would be unrealistic to anticipate that any significant residential or economic development will occur. Thus, while BART was opened at a time of relative economic buoyancy in the Bay Area, the impact of the system on the regional accessibility surface has been negligible. Second, it is possible for both of the above conditions to be fulfilled and for the development potential of a new rail investment not to be realised because of the absence of a policy and public sympathetic to the development of specific locations along a major corridor. Such a policy and attitude has played a vital role in the development of specific METRO station locations in Toronto, for example, while being conspicuously absent from the BART planning process.

The evidence clearly points to the critical need for a highly integrated planning strategy. Without such a strategy there is little evidence to suggest that market forces will, of themselves, result in the localized development potential created by major public transport investment being realised in preference to that created by other factors.

4. Critical Indicators of Development/Urban Structure Change

The discussion of both the development expectations and experiences associated with major urban public transportation investments suggests a need to concentrate more attention on certain indicators that are not typically assessed in conventional studies. Such indicators include:

- the development of better measures of "before" and "after" or "with" and "without" accessibility for firms and households so that the relative impact of an increase in the supply of public transportation or the overall metropolitan accessibility surface can be assessed. The smaller this relative shift, *ceteris paribus*, the smaller the potential impact on development/urban structure.

- the development of measures of urban economic development, so that the timing of the increase in public transportation supply can be matched with the metropolitan area's economic growth cycle. Time series rates of office construction/employment growth, retail turnover growth, and single/multi-family housing starts would be useful in this respect. Again, the greater the overall rate of economic growth during the construction and initial operational period of a new public transportation facility, the greater the potential development/structural impact.

- specification of time series changes in key urban characteristics such as transit patronage and coverage, densities of office/retail employment, and single/multi-family housing along the major radial corridors. The cross-urban area comparison of such characteristics can be invaluable in assessing the consistency of existing urban structure and proposed major changes in the supply of public transportation.
- critical review of financial, institutional, and policy basis necessary for promoting and achieving public transportation-related development at selected locations and the assessment of likely community attitudes to such development.

The overall conclusion is that the prediction of the land use impacts of major transport projects is a very difficult business, depending on a variety of interacting factors that are difficult to measure and predict. The clear implication of this review is that projects should not be undertaken when a specific land use/urban development outcome is essential. The planner and the investor must be prepared to accept different outcomes and must be sure that none of the possible outcomes will jeopardize the project. The art in making such investments lies in establishing the prerequisites--in terms of planning and business climate and investment timing--that will maximize the probability that the most desirable outcome will occur. Recent evidence indicates, however, that in many cases the best-laid plans may well go seriously astray.

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ECONOMIC DEVELOPMENT AS A CRITERION FOR TRANSPORTATION INVESTMENT IN THE UNITED STATES

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Abstract

The United States in the early 1980s has established improved performance of its economy as a priority goal. Specifically, it desires to produce its products at lower costs, thereby lowering inflation and unemployment at home and increasing the competitiveness of its products abroad. Transportation is one of the elements which impacts the costs of U.S. products, and a mathematical expression is presented in this paper which helps describe this impact. Transportation decisionmakers, operating in an era of constrained resources, and attempting to justify transportation investments and disinvestments on the basis of impacts on the economy, need to understand this expression since it provides a foundation for analysis more specifically aimed at economic goals than conventional approaches.

Examination of recent U.S. transportation studies related to public policy decisions on economic development reveals an array of projects conducted by many different types of agencies and using in each case ad hoc procedures and techniques. The Transportation Research Board has developed a tentative system of classification for such projects which can be used as a basis for establishment of a broader research agenda in this field. This system is described herein.

In recent years transportation policymakers at the Federal level have been almost compulsive in their attempts to use transportation as a lever in efforts to address a large number of society's ills. Some of these ills are transportation related, others less so. Transportation programs have been launched to improve the mobility of those in inner city ghettos, to reduce environmental pollution, to influence urban development patterns, to increase mobility in rural areas and for the elderly and handicapped, to conserve energy, and to reduce the obtrusiveness of government by eliminating regulations. Without respect to the merits of these programs, it is clear that political awareness and public sensitivity to the respective underlying social problems have been influential in their establishment. In some cases these have resulted in only marginal achievement of original expectations.

The recent U.S. elections have provided the latest in this series of issues: economic development. Concern for the economy of the nation is seen on all hands as the number one priority of the new administration. "Innovation, reinvestment, productivity" and "supply side economics" are the latest "buzz words," and it cannot be much of a surprise to discover that relationships between transportation and economic development are now seen as an urgent issue in need of definition, elaboration and exploration. Shortfalls in the delivery of transportation services have gained media attention several times recently, particularly in connection with the shortage of railroad cars to move grain and the difficulties in transportation of export coal, and these have served to further underscore the transportation-economy relationship in the public consciousness.

In contrast to some previous efforts to load transportation programs with only marginally related social goals; in this case, transportation may well be a vital, and perhaps, even an essential component of any strategy for "revitalizing the nation's industry." A significant portion of the costs of some consumer goods is in transportation. About one-half the total cost of an Idaho potato purchased in New York is in transportation. The cost of transportation of U.S. grain to the Soviet Union is about one-half the cost of producing the grain initially. Precise figures are difficult to find, but some economists have estimated that about 40% of the costs of some finished goods is in transportation, including the original movement of raw materials, intermediate movements and final distribution. If this is even partially true, then any serious efforts at increasing overall productivity must take a long look at the role of the transportation sector.

The general consensus that seems to be emerging about viewing transportation as a part of our economic system--even as a conceptual abstraction--is in contrast to our ability to measure the importance of a component and to distinguish between those situations where a component is vital and other situations when it is not. In fact, even the words "economic development" and "productivity" as used among transportation people are usually imprecise and ambiguous terms that mean different things to different people. "Economic development" to many transportation analysts is synonymous with land development around mass transit stations, airports or other terminal facilities. "Productivity" is understood to mean the delivery of the same or improved transportation services while using less people, equipment or other resources. These definitions, and the narrowed perspectives that accompany them now, require broadening if we are to respond to the new economic imperatives. What we seek is a better understanding of the role of transportation in the production of goods and services desired by consumers and industry. Transportation, in this sense, is an intermediate good used, in the main, as a tool in the production of other products and services. The nation is looking, almost feverishly, for ways to reduce the costs of these products and services, so that our prices can be reduced to produce less inflation at home and produce more competitiveness in international markets. These costs can be lowered by improving our productivity--that is, by producing the same or better products while using fewer resources, materials, labor, equipment, energy, transportation, etc. Thus, transportation is but a component in production and its improvement only one of several possibilities in each potential effort at raising productivity.

Conventional transportation planning, with its emphasis on analysis of internal transportation efficiency, for example, selecting the project which hauls the anticipated transport demand at the least economic, social and environmental cost, should continue in most instances. But, such analyses may not adequately distinguish between optional uses of scarce transportation improvement funds. Whether at the local, state or national level, businesses are now more prone than in the past to ask for government assistance when they feel threatened. Open, barefaced assistance pleas are often difficult to spurn, especially if large numbers of jobs are at stake. It is even more difficult to spurn a request for transportation improvements since the provision of infrastructure including transportation is more traditionally seen as a public responsibility. In such cases government decisionmakers, as a minimum, must know whether such improvements will reduce the product costs sufficiently to make the product competitive. If transportation investments are made on economic improvement grounds and a loss in business and jobs occurs anyway, then everyone loses. The analyses of such situations clearly require investigations beyond the transportation system itself.

International finance institutions concerned with economic development in developing countries have concerned themselves with this problem for many years. Decisionmakers in capital-starved economies must choose the areas of investments that have the best chance of reducing the costs of internally produced products or commodities such that these products can be successfully exported or afforded domestically by low income residents.

Often, the conclusion is drawn that transportation investments meet this criterion, usually as part of larger lending packages. Sometimes the construction or improvement of a critically located rail or road link can open up the interior of a country, so that raw materials or finished products can be marketed successfully to other countries. In contrast, in the United States, most of the nation's area is already accessible, often by multiple modes. Opportunities for any single new transportation link to make a quantum jump in accessibility are few. On the other hand, we may have a more extensive transportation network than we can afford, or need. The mileage of the nation's rail system has been declining steadily for many years. There is also some evidence that some elements of our highway system are in a state of decline. Raising money for maintenance of many of our highway bridges is becoming difficult, and load restrictions are becoming more prevalent. Often when a rail segment is scheduled for abandonment, or a highway bridge is restricted or closed, the issue of the local economy is raised since local businesses depend on such links. Obtaining money for maintenance or rebuilding often must then be justified in terms of economic necessity.

Political and economic necessity may be synonymous at the local level, but at the national level we may have to face the fact that we have more system than is necessary, and hard economic choices will have to be made between those links which can be justified in economic terms and those which cannot. To do this will require an analysis of the impact of the link on costs of products and services which use the link--an analysis broader than the question of the internal transportation efficiency of the link (and its connecting subsystem).

This distinction can be illustrated more clearly by using some mathematics. First, I must postulate that the cost of a product is at least, in part, a function of the cost of materials used in its production and the cost of transport of those materials to the processing or assembly point. Let us say that a^{mn} is a variable that tells how much material m is required to make one unit of product n. For example, a^{13} could be tons of ore (m=1) required to make one ton of steel (n=3), and a^{23} could be tons of coal (m=2) required to make a ton of steel.

We can also let p^m_i be the unit price of material m at origin i. For example, p^1_1 could be the price of a ton of ore (m=1) at Duluth (i=1), and p^2_2 could be the price of a ton of coal (m=2) at a West Virginia mine (i=2).

Let us say that t^m_{ij} is the cost of transporting a unit of material m from origin i to destination j. For example, t^1_{13} could be the transportation costs for a ton of ore (m=1) from Duluth (i=1) to Pittsburgh (j=3), and t^2_{23} could be the transportation costs for a ton of coal (m=2) from the West Virginia mine (i=2) to Pittsburgh.

Finally, let C^n_j be the cost of producing a unit of product n at assembly point j. For example, C^3_3 could be the cost of producing a ton of steel (n=3) in Pittsburgh (j=3). Then

$$C^n_j = \begin{array}{l}\text{Costs of materials}\\ \text{at points of origin}\end{array} + \begin{array}{l}\text{Costs of transporting}\\ \text{materials from origins}\\ \text{to destination}\end{array} + \begin{array}{l}\text{Other costs}\\ \text{(e.g., labor}\\ \text{plant, etc.)}\end{array}$$

The cost of a ton of steel in Pittsburgh is:

$$C^3_3 = \left(p^1_1\, a^{13} + t^1_{13}\, a^{13}\right) + \left(p^2_2\, a^{23} + t^2_{23}\, a^{23}\right) + \text{(Other costs)}$$

In general for any product n produced at location j with any number of material inputs m the expression becomes:

$$C^n_j = \sum_m \sum_i \left(p^m_i\, a^{mn} + t^m_{ij}\, a^{mn}\right) + \text{(Other costs)} \qquad \text{(Equation 1)}$$

In Equation 1, other costs are held separate from the main terms of the equation for simplicity. However, there is no reason that they cannot be accommodated like any material cost in the equation. For example, in the case of labor, the meaning of p^m_i can be extended to represent the hourly cost of labor (since labor is normally purchased at the plant site i=j, for labor) and a^{mn} can represent the number of hours of labor m to make a unit of product n. The term t^m_{ij} is zero for labor, assuming that laborers pay their own transport cost to work and have included these costs in their wages. This somewhat formidable expression deserves some serious examination by all who are interested in transportation's role in the economy and in possible approaches to analysis of these issues. At the national level our objective is to reduce $\sum_n \sum_j C^n_j$ (cost levels for all products n at all locations j), for in so doing we will have overcome inflation. The equation shows transportation's role in this overall cost reduction effort. Some products are such that $t^m_{ij} a^{mn}$ (transportation costs associated with the production of n at j) is small compared to $p^m_i a^{mn}$ (costs of materials or labor m at point of origin i) and the potential for reducing C^n_j (cost of the product n at j) as a result of transportation improvements in such cases will likely be small. On the other hand, where transportation costs are a large part of the total, the opportunities for real product cost reduction as a result of transport improvements could be great. Transportation analysts and planners must grasp, use, and articulate this basic concept if they are to make appropriate choices about future transportation investments.

Up to now transportation planners have been concerned primarily about finding ways (either through management and operational improvements or through investments in better transportation facilities) of reducing t^m_{ij} for all ij pairs (origins and destinations) and all mn combinations (materials m required to make products n) served by the subsystem being analyzed. Clearly any reduction in t makes some reduction in C, but the relative importance of alternative ways to reduce t can be much better understood by understanding their relative impacts on C, since reduction in C is the ultimate goal.

It might appear at first glance that use of Equation 1 would mean that transportation costs $t^m_{ij} a^{mn}$ would only appear relatively large in bulk products involving low cost per unit weight (e.g., grain, coal, etc.) which must be hauled long distances. However, it must be noted that t includes warehousing and inventory costs as well as costs of physical movement. Inventory savings of an expensive product (e.g., semiconductors) have sometimes dictated high speed expensive transportation modes (e.g., air express) such that $t^m_{ij} a^{mn}$ could be unexpectedly large for such products.

The potential for large benefits from transportation improvements then would most likely occur where "ta" is relatively large compared to "pa" (in Equation 1); it also would be likely to occur where demand for a product is relatively sensitive to price as is the case in Figure 1 where a small cost reduction results in large increases in demand. Increase in demand, particularly when such demand originates overseas or comes from local consumption of domestic goods instead of imported goods, results in increased employment, domestic profits, and surpluses in international trade accounts.

Conversely, Figure 2 shows the situation where transportation improvements might well result in significant reductions in transportation costs, but other factors (e.g., increasing labor costs, plant obsolescence, increasing raw materials or energy costs) could be expected over time to increase total production costs, despite offsetting transportation savings, such that q would go to zero (the business goes bankrupt).

A similar situation with a different root cause is shown in Figure 3 where potential transportation cost savings will be more than offset by predictable decreases in product demand. This situation could occur when the product is being made obsolete by new technology (e.g., semiconductors replacing vacuum tubes), by external market factors (e.g., small cars replacing large cars) or expansion of competitor capacity and capability (e.g., the Japanese invasion of the American market in electronics, cameras, autos, etc.).

Clearly, transportation decisionmakers must avoid commitment of scarce transportation investment resources into situations where the transportation investment will not, by itself, be able to offset underlying economic realities which insure defeat. Yet, we must have the ability to distinguish between cases like Figure 1 (where transportation can help), and Figures 2 and 3 (where it cannot). Also, we must have tools which enable us to understand transportation contributions to production costs if we are to properly make such distinctions.

To reiterate, we must focus on those transportation improvements which can have a significant impact on lowering the costs of U.S. made products; and, of those, the highest priorities must be given to those serving industries where relatively small cost reductions have the potential for large expansions in product demand, thereby increasing jobs, secondary economic activity (plant housing, etc.) and Gross National Product (GNP). Equation 1 provides conceptual insight into transportation's role in all this and, therefore, provides a conceptual approach to the development of analysis tools needed for proper planning in this new environment.

Where Do We Begin?

In many respects our situation in 1981 is parallel to the one we faced in the early 1950s. At that time there was a growing awareness that large sums were likely to be spent in our cities for highway improvement largely related to the large interstate highway program then gathering steam. Clearly, the need for planning these huge projects within our cities was going to be an enormous effort for which we had few trained people, limited methodology, data and organization. The next ten to fifteen years were spent working through these problems, and there may be disagreement as to how successful we were. There was, nevertheless, a great deal learned about urban transportation demand and supply relationships during that period. The lesson here for U.S. professionals is that we do not seek nor are we likely to find overnight solutions to our current plight. As we view the problems of making transportation decisions based on comprehensive economic criteria, they include, as before, deficiencies in trained manpower, methodology, data and organization. Our current problem also has an added complexity--a dimension of boundlessness.

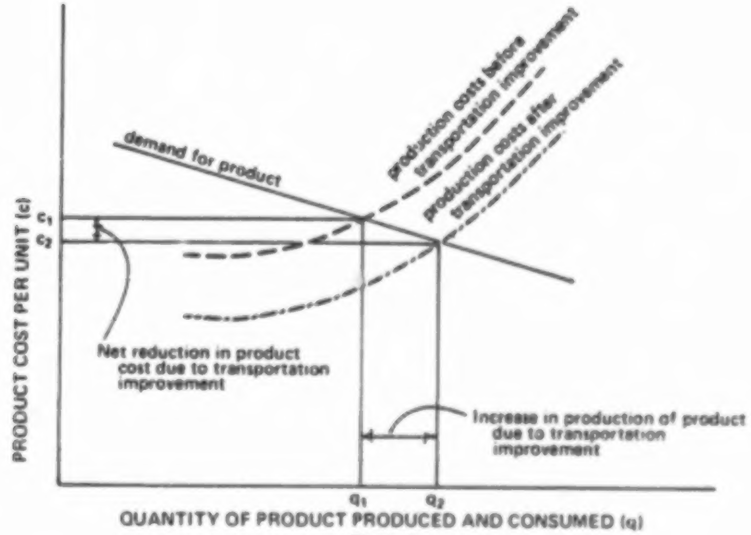


Figure 1.

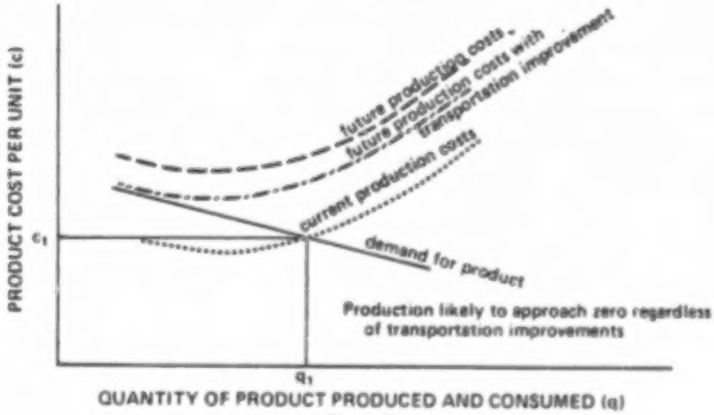


Figure 2

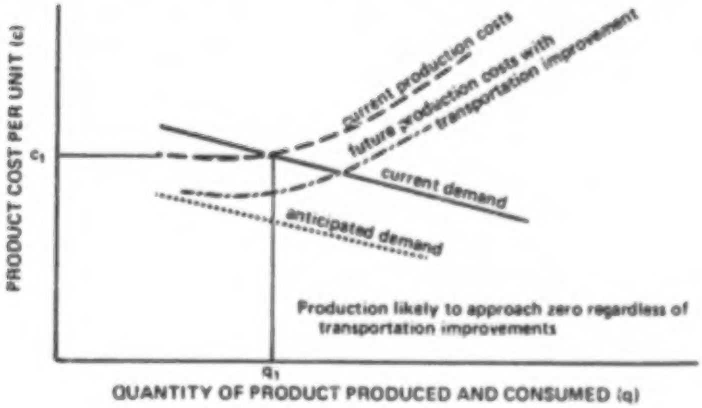


Figure 3

BEST DOCUMENT AVAILABLE

Geographically, the problem always seems to extend well outside the influence areas of the agency doing the analysis, in many cases extending outside national boundaries. Functionally, a broad array of our institutions is concerned with economic development, whether they be public or private; certainly, transportation agencies see their roles as substantially short of planning the entire economy. Most anyone, then, actively researching the area with a scope sufficiently comprehensive, may be seen as guilty, at best, of going outside their charter and, at worst, of treading on someone else's turf.

Government agencies particularly are reluctant to move into the area because of our national ambivalence about the role of government in our economic life. Most of our freight is moved by the private sector and most of us hope that it will continue to be. Yet major problems continue to rise at many points of the interface of private and public responsibility zones. An example is the issue of continuing service on our bankrupt eastern railroads. Even the most conservative members of the new administration suggest only that the Federal role be reduced. This still leaves the states and private groups to pick up the rest. The need for analysis tools is clear, if only to decide where the boundary between private and public responsibilities should be located. Issues such as airport development, branch rail line subsidies, and inland waterway improvements--all lie at the interface, all require justification in economic terms, and all require decisions year after year. Moreover, they all tend to require multimodal analysis since a decision in one mode inevitably affects competing modes.

Each of these problems is seen by those who must deal with them as special problems, unique unto themselves and unlikely to arise again. Since no one sees his role as comprehensive in even a transportation sense (let alone in an economic sense), no one feels any responsibility to increase our overall capabilities of analysis in this area. The individual modal administrations within the U.S. Department of Transportation, where most Federal transportation money is spent, certainly do not see their roles as multimodal. The Office of the Secretary of the U.S. Department of Transportation has only in recent months seen any long-term interest in the problem. A few of the State transportation departments are perhaps thinking more comprehensively than others; but even here, in addition to the obvious geographical constraints, any given State is concerned with the problem only for a fairly limited set of local commodities. (For example, Iowa has made significant progress, but primarily in the problem of grain movements.) Thus, while the problems are real enough, our institutional arrangements do not lend themselves to launching the necessary research for eventual solution.

The thousands of agencies, public and private, that operate our vast transportation system are in some ways similar to oarsmen in a vast lifeboat--all rowing furiously. Occasionally we notice that our oars bang together and that we are not pulling in the same direction, and once in a while someone comments that no one is in the helm. We probably do not have to be ready to put anyone in command of the ship to pause for a moment and agree on some voluntary rules for rowing in unison.

A Framework For Discussion

In response to the general set of problems enumerated above and with the recognition that research is a necessary component of moving towards solution, the TRB empanelled a group of twenty experts for a two-day workshop in December 1980. The group included analysts who were able to represent the state of the art in the field as currently practiced. It also included decisionmakers currently charged with making some of the difficult choices referred to earlier. As a whole, the group was broadly representative of the disciplines and agencies concerned with the subject area. In preparing for the panel and its agenda, it became apparent that the group would have to be small because of the necessity for a relatively unstructured agenda. It was anticipated (correctly) that since each participant would bring to the meeting such a varied perspective, vocabulary and approach, to the questions, that getting a consensus, or even determining whether a consensus existed, might prove difficult. On the other hand, it also became clear that it would be impossible to include all the agencies and groups that have a direct and legitimate interest and activity in transportation and economic development. For example, we were unable to include typical representatives of the local and state economic development agencies set up by many governments to attract jobs and development to their areas. Several important constituent agencies within the U.S. Department of Commerce were not in attendance (the Maritime Administration of the U.S. Department of Commerce did participate), nor were there sufficient numbers of private sector groups and firms with direct and relevant interest in the subject area. Nevertheless, I believe this first panel will succeed in arriving ultimately at a method of structuring a larger meeting that includes a broader and more representative group (another meeting is anticipated in the early spring).

The committee's objectives were to gain a clearer understanding of the problem, establish the parameters, if possible, and find a method to compartmentalize the problem so that its components could be ranked in order of importance, thus providing a basis for a point to begin work. We also hoped that such a compartmentalization process would improve our ability to communicate with one another through a clarification of our terms of reference. Finally, the committee wanted to identify current issues, techniques and methodologies now available, and to identify next steps.

The committee decided that the ultimate consumers of the continuing research efforts in the field were the public decisionmakers. The private portion of the transportation sector is still largely single modal in character and their objectives are to maximize the income of their shareholders, both in the short and long term. The committee doubted that our job was to find ways to improve directly their ability to perform that task, though there was certainly no objection to private sector use of whatever techniques which ultimately evolve from this process. A look at the issues described previously (i.e., to analyze multimodal transportation problems and solutions and evaluate them on the basis of their expected impact on the productivity of our overall economic sector) indicates that they are predominantly public sector problems.

As shown in Figure 4, four major dimensions can be used to characterize a transportation-economic (TE) analysis:

1. Scale of Analysis: A look at current issues indicates that analysis approaches will vary depending on the scale of analysis. For example, many states and local communities are faced with decisions about investment in plant access roads, local rail branch subsidy, and local bridge repair. While perhaps all could agree that the influence area, of economic impacts of such projects extends significantly beyond their immediate environs, the impact and thus the analysis could be largely assumed to be local in character.

   Through a similar rationale, techniques and data requirements for local, state, regional and national problems may all require different approaches.

2. Level of Interest: Governmental interests at all levels can be expected to have concerns about economic problems. While there is a correlation between scale of analysis and the level of interest, the two are not the same. Some classes of issues (for example, analysis of the Great Lakes Ports) might be conducted at the regional scale, but have a high level of interest from all levels of government from Federal to local.

3. Comprehensiveness of Information Required for Decision: Four different categories of analysis output were identified here. Perhaps in an ideal world, we would provide decisionmakers with a comprehensive analysis of all projects. Some, however, do not warrant such an analysis and the limits of available time and other resources often preclude a comprehensive analysis. The four categories identified are:

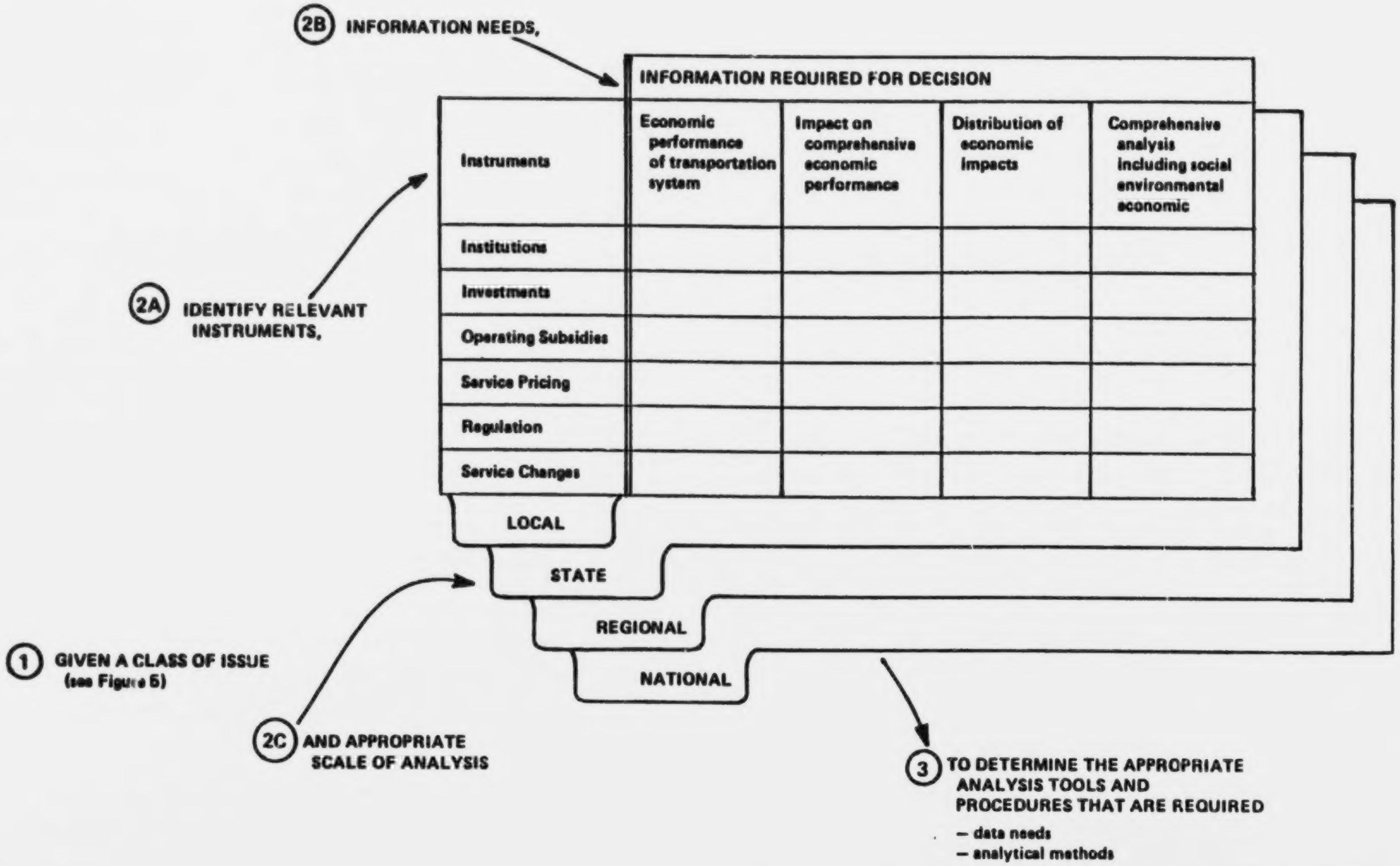
   a. Analysis of the economic performance of the transportation system itself: This would include the conventional revenue--cost and benefit-cost analyses. Methodologies for these types of analyses have been standardized by the World Bank and some countries as the basis for many investment decisions.

   b. Impact on comprehensive economic performance: This refers to the examination of transportation as part of the productive system, as described earlier in the report.

   c. Distribution of economic impacts: This refers to the need in some instances not only to calculate the benefits of alternate improvements to the entire economy, but also identify and evaluate which groups obtain what level of benefits, that is, who are the winners and losers and by what amounts.

   d. Comprehensive analysis, including social, environmental and economic evaluation: Such an analysis would be truly comprehensive including the elements identified in a, b, and c, plus the other externalities.

FIGURE 4. AN APPROACH TO TRANSPORTATION-ECONOMIC ANALYSIS.



Instruments	Economic performance of transportation system	Impact on comprehensive economic performance	Distribution of economic impacts	Comprehensive analysis including social environmental economic
Institutions				
Investments				
Operating Subsidies				
Service Pricing				
Regulation				
Service Changes				

① GIVEN A CLASS OF ISSUE
(see Figure 5)

(2A) IDENTIFY RELEVANT INSTRUMENTS,

(2B) INFORMATION NEEDS,

(2C) AND APPROPRIATE SCALE OF ANALYSIS

③ TO DETERMINE THE APPROPRIATE ANALYSIS TOOLS AND PROCEDURES THAT ARE REQUIRED
- data needs
- analytical methods

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While no one would claim that we are satisfied with our abilities in any of the categories, it seems clear that we know the least about and have had the least experience with categories b and c above, and these categories are, of course, the focus of this paper.

4. Instruments: The final dimension identified as "instruments" refers to the fact that techniques for evaluation can be influenced by the policy instruments needing evaluation. These policy instruments include new transportation investment, operating subsidies, pricing, regulation, operational changes, and institutional changes.

As indicated in Figure 4, these four dimensions, properly applied, can provide a basis for classification of techniques depending on the class of issue being addressed.

Figure 5 indicates four classes of issues that were identified by the committee as within our current experience in the United States. While it is doubtless that further discussion will identify other issues not shown on Figure 5, it is believed that the classification scheme shown in Figures 4 and 5 will accommodate additional issues as they are identified. The scheme also provides a basis for structuring a larger, more appropriately diversified meeting that includes many interests involved in the subject. For example, workshops could be held to allow for more expansive treatment of existing techniques, their deficiencies and research gaps for each of the four classes of issues shown.

Conclusion

This paper has argued that a consensus is currently emerging on a need for multimodal analysis of transportation issues which focus on a view of the transportation system as part of the productive sector of the overall economy; and that there is a scarcity of data, techniques, and trained manpower to address these issues. The paper has distinguished between the type of analyses performed in the past from those believed currently needed. It has also identified a classification scheme that can be used as a basis for approaching research agenda.

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FIGURE 5. PRIORITY RESEARCH AREAS.

	CLASS OF ISSUES (Examples)	LEVEL OF INTEREST	SCALE OF ANALYSIS	PROBABLE INSTRUMENTS
1	COMMODITY-SPECIFIC NATIONAL ISSUES Coal Grain Containers	STATE, FEDERAL	NATIONAL	INVESTMENT, PRICING, SUBSIDY, REGULATION
2	REGIONAL MULTIMODAL (MULTI-COMMODITY) Ohio River Great Lakes Ports Upper Mississippi New Orleans Locks Eastern Railroads (Conrail)	FEDERAL, STATE, REGIONAL, LOCAL	REGIONAL	INSTITUTIONS, INVESTMENTS, PRICING, SUBSIDY, REGULATION
3	LOCAL PROJECT INVESTMENT/ SUBSIDY (for economic development) Local Airports Highway Projects Rail Branch Lines Intermodal Ground Terminals Ports	STATE, LOCAL	LOCAL	INVESTMENTS, PRICING, SUBSIDY
4	SYSTEM EFFICIENCY (for economic development) (non location specific) Truck Size and Weight Truck Back Haul Truck Terminals Rail Issues (e.g. Unit trains, COFC) Other	LOCAL, STATE	NATIONAL, REGIONAL	INSTITUTIONS, PRICING, SUBSIDY, REGULATION
5	OTHER	——	——	——

ECONOMIC DEVELOPMENT AS A CRITERION FOR TRANSPORTATION POLICIES: A SPATIAL PERSPECTIVE

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Abstract

This paper argues that the allocation of transportation investments across regions and across modes should reflect sectoral and regional growth patterns of industry. As new economic policy initiatives in the United States make economic change inevitable, strategic transportation planning must explore the implications of prospective changes. The explicit spatial focus of transportation infrastructure investments in turn provides an important perspective for the analysis of economic development policies with significant regional impacts.

The first part of the paper reviews the present knowledge regarding the interactions between transportation investment policies and economic development patterns. Focusing on two major approaches to the analysis of these interactions, industry location analysis and strategic investment evaluations, the paper shows that our understanding of the relationship between transportation and development and its causal structure is still rather sketchy. It does not allow for deriving any firm performance criteria for the transportation system from economic policy goals (or the expected industrial impacts of economic policy initiatives). Even so, a spatial perspective suggests that transportation policies can play a significant role in accommodating the changing demands associated with changing residential and industrial location patterns.

The discussion suggests a series of questions relevant for a strategic transportation policy assessment based on a spatial perspective of economic development patterns.

Introduction

Faced with escalating budget pressures, planners and policymakers in the United States have begun to question long-standing premises regarding the role of the public sector in transportation. New policy priorities complicate this reassessment. Economic recovery heads the list. The need to overcome the perceived malaise of the U.S. economy, slow productivity growth and an apparent erosion of competitiveness in international and domestic markets dominates the formulation of broad policy strategies. In the new era of fiscal restraint, economic development impacts become key criteria for evaluating transportation infrastructure investments as well as regulatory or tax/subsidy policies.

Economic development is by no means a new concern for transportation planning. Direct and secondary economic impacts have always played a major role in the evaluation of policy alternatives and investment projects. Efforts to exploit opportunities for joint development have become standard elements of urban transportation investment projects--using the public commitment to attract private developers to new transit malls or rail stations. Similarly, improved access has long been regarded as an essential element in developing lagging regions.

Even so, evaluating strategic policy alternatives with respect to their relationship to economic recovery in a country like the United States, with a highly developed infrastructure, moves into new territory. This paper looks at the tools available to explore the interactions between the spatial allocation of transportation investments (among and within regions) and economic development patterns. Economic development is interpreted in the traditional sense--a composite of capital formation, employment growth, rising productivity, and related factors.

The paper concludes that the available evidence lends no support to the contention that the spatial allocation of transportation investments could be used as an instrument in engineering economic recovery. Rather, transportation planners should be concerned with the implications of alternative paths to economic recovery for the allocation of transportation investments. However, our understanding of the sensitivity of economic development with respect to transportation investment patterns and vice versa remains rudimentary. The paper concludes with some suggestions for exploring these interactions at the strategic level further.

Transportation-Development Interactions

Analytical Approaches

Interactions between transportation investments and economic development have been documented for widely differing settings, ranging from the role of rural roads in the transformation of traditional subsistence agriculture to the impact of beltways on the economic health of central cities in the United States. In spite of this extensive documentation, the understanding of the actual process of interaction and its causal structure is limited. It cannot provide sufficient guidance to planners and policymakers in allocating resources to transportation investments, or in deciding how these resources could be used best to support some desirable economic development path.

This paper focuses on the relationships between transportation infrastructure investments and regional economic development patterns. Three major analytical approaches have been used in examining these relationships:

1. Incremental evaluation applies to a particular investment project; this traditional cost-benefit analysis treats the change in transportation system characteristics resulting from the project as marginal under a ceteris paribus clause;

2. Strategic evaluation examines the long-term and secondary impacts of a transportation infrastructure investment program or strategy, such as a major highway system; this approach focuses particularly on the impact of a given system on the spatial structure of the economy.

3. Industrial location analysis looks at the influence of differences in accessibility among alternatives on the firm's location decision in the context of the neoclassical theory of the firm.

All three approaches in essence presuppose a causal direction from transportation infrastructure investments to economic impacts, either at the project level, at the national level, or at the level of the firm. Generally, that premise is not fully borne out by empirical research. Barloon (1965) summarizes the position of several researchers: "changes in industrial output and in location appear to alter the structure of transportation rather than the converse...". That view implies that industrial location decision and associated population redistribution trends are fairly independent of the structure of transportation infrastructure investments, at least in a country with an ubiquitous transportation system.

The position expressed by Barloon does not conflict with the conceptual approach of incremental evaluation at the project level, since projects may well be chosen to accommodate changes in industrial output and in location. However, it is inconsistent with the underlying premise of industrial location analysis and strategic evaluation. A brief review of these analytical approaches is therefore necessary to examine any theoretical underpinnings and empirical findings.

Industrial Location Analysis

Location theory and analysis examine the microeconomic determinants of a firm's location decision in the framework of neoclassical analysis, under the assumption of profit-maximizing behavior of the firm. Location theory introduced the notion of space into economic analysis. Based on the original contributions of Weber (1919), Losch (1954), and Isard (1956), location decisions are not studied as part of the neoclassical theory of the firm. In fact, Alonso (1964) argued that the theory of industrial location was essentially complete: "significant contributions to location theory have become rare." (p. 78)

Within this neoclassical context, the optimal location of a firm is determined by the spatial distribution of demand for its product(s), the distribution of labor and other inputs, and the structure of the transportation system that determine total transportation costs for alternative locations. The formulation of the neoclassical location model emphasizes transportation costs as descriptors of locational advantages. Consequently, the location decision should be quite sensitive to any policy action modifying transportation cost parameters. The conclusions of location theory are embedded in the specific formulation of the problem. The abstractions required for the theoretical analysis have hampered the empirical assessment of the theory's validity.

Empirical studies of industrial location decisions lack the conceptual rigor of location theory. For example, in a recent review of the state of the art in location analysis, Brown (1979) observes that the "review of the theoretical literature in plant location has uncovered many testable hypotheses, yet for the most part the empirical literature...does not test these hypotheses." Oster (1975) agrees with that assessment, arguing that many location studies are "product(s) of seat-of-the-pants ad hocery, rather than even quasi-rigorous analysis."

Oster distinguishes two major types of empirical location studies--revealed preference analysis and survey work. Revealed preference analysis examines actual location decisions and the resulting patterns, and their associations with place characteristics assumed to be independent. One of the principal problems with this approach, which typically has to work with cross-sectional data, is the simultaneity bias--place characteristics may be as much a result of industrial location decisions as their determinants. That problem applies to transportation system characteristics in particular; the causality may well run in the other direction, as noted before. Thus, while several studies--notably Moses and Williamson (1967) or Hopkins (1972)--have found evidence for a positive influence of transportation availability on location decisions, the reliability of these findings is suspect, given the possible bias of the estimates.

Moreover, recent empirical work fails to confirm the association between transportation system characteristics and industrial location. Czamanski (1981) examines location patterns of selected industries as a function of several index variables describing accessibility, labor force characteristics, and other place features.

A measure of the general transport advantage, summarizing the ease of access to markets for inputs and products, performs satisfactorily in categorizing metropolitan areas into "successes" or "failures" in attracting firms within different industries. Even so, the overall evidence leads Czamanski to conclude that the transport of goods "does not seem to play the overwhelming role assigned to it by classical location theory." (p. 41) This result may reflect some inherent weakness of neoclassical location theory with its somewhat tautological arguments. It may also be seen as supporting the rather popular contention that the evolving transportation technology and a highly developed infrastructure have freed up industrial location decisions.

The evidence generated by surveys seeking to determine the major factors influencing industrial location decisions is no more persuasive than that produced by the revealed preference work. Oster (1975) summarizes the findings of retrospective surveys (asking managers to list the factors they considered in choosing a plant's location) in four propositions:

1. Overall, the major determinants of location are proximity to markets, availability of labor, and transportation.

2. The determinants of location, however, vary fairly significantly by the structure of firms.

3. Firms typically do not engage in extensive search across alternative sites. However, the degree of search does vary across firm types.

4. Uncertainty and personal attraction to an area matter in the firm's location decision.

Specifically, Harris and Hopkins (1972) found that more firms' location decisions were sensitive to output transportation costs than to those for inputs. In a number of surveys, transportation ranked first among the location criteria listed. Qualitative aspects of a transportation system's performance, particularly reliability, appear to become more important than basic availability.

With respect to input transportation costs, labor commuting needs have been found to play a role in location choices. Vaughn (1977) suggests that companies depending on skilled labor would increasingly have to move to the suburbs. In contrast, Chicago companies surveyed by Hartnett (1972) that relied more on unskilled labor looked for access to public transportation. These trends reflect several causes, such as different automobile ownership and use patterns, or increasing congestion in urban centers.

In summary, empirical research on the determinants of industrial location choices presents a somewhat mixed picture. Most studies found some indications that transportation system characteristics play a significant role, but very little is known about the actual strength of any influence or its nature.

Evidence from surveys is presumably biased by *ex post* rationalizations of certain decisions. Revealed preference analysis thus far can say little about the direction of causality in any observed association between transportation system characteristics and industrial development. Further research, employing a more rigorous conceptual framework, is needed. One necessary step, stressed by Czamanski (1981), is the analysis of location decisions in a dynamic context to assess not only the strength of association, but also the direction of causality.

Strategic Evaluation

The strategic evaluation approach focuses on the linkages between a particular strategy in developing the transportation system of a country or a region and spatial economic development patterns. The formulation of an adequate conceptual framework for such an analysis presents an extremely complex task. It requires abstraction from the microeconomic postulates of transportation-development interactions to derive specific hypotheses at the regional level. Basically, one faces the same problems one encounters in the cost-benefit analysis of individual projects, but magnified several times. The microanalytical problems and possible solutions have been outlined in a number of studies and textbooks, such as Charles River Associates (1972). Looking at the interregional impacts of transportation strategies at the national level changes not only the scale but also the complexity of the analysis.

In addition, any strategic evaluation must cope with the issue of what secondary and higher-order effects should be considered. Any changes in a socioeconomic system as a result of certain policy decisions trigger others, which also affect development patterns. The problems of dealing with such induced effects, Myrdal's "circular cumulative causation," have been discussed extensively (and largely inconclusively) in the economic development and planning literature. In practice, it introduces considerable uncertainty in tracing the effects of a particular policy, because any causal links are becoming increasingly tenuous.

As a result, the few attempts at strategic evaluation of the transportation-development link remain exploratory in nature. One of these examples, in fact, is more a planning exercise, the Harris model. Curtis C. Harris Associates (1974) used a complex multiregional, multi-industry forecasting model to predict the impacts of alternative national highway systems. The different system alternatives were assumed to affect (predicted) regional growth patterns by (a) lowering transportation costs, (b) changing congestion levels within a region, and (c) temporarily increasing construction activity levels within a given region. The results of the simulations indicated some redistribution effects for alternative policies, especially for small and poor areas. An assessment of the usefulness of these findings for transportation policy formulation is hampered by underlying weaknesses of the model. The relationships used in the model are based on an econometric analysis of the determinants of firm location that is subject to all the problems mentioned above in the discussion of industrial local analysis. The statistical relationships and their significance levels give little cause for much confidence in the findings of the simulation analysis.

Another attempt at strategic evaluation, in this case for Great Britain, used an approach akin to historical simulation to determine the effects of the completion of a major road building program. Botham (1980) derived measures of market accessibility, originally developed by Harris (1954), to describe alternative transportation systems. He used these measures to estimate the regional distribution of employment without the road construction program, as well as for an earlier completion of the system. The comparison of the actual employment distribution to the hypothetical ones suggests that the impact of the road program is small.

Botham's analysis raises many questions. Constructing the hypothetical alternatives and tracing their location implications require some heroic assumptions. In addition, the focus on total rather than sectoral employment may conceal some significant shifts in industrial distribution attributable to the completion of the construction program. Even so, the overall approach deserved attention as one option for exploring major regional impacts of particular infrastructure investment policies.

Other studies have focused on specific aspects of a strategic evaluation. For example, several researchers have attempted to assess the relative influence of population movements to industrial location decisions. Wheat (1973) finds that previous population growth stimulates employment growth by establishing a market. However, as Vaughan (1977) points out, a growing population also means a growing labor force. Thus, the "results do not indicate whether consumer demand or labor supply is exerting the dominant influence." In any case, this particular example illustrates the possibility of indirect effects of transportation investment policies on economic development, by contributing to a geographical redistribution of the population. Technological change and infrastructure development have lowered commuting costs, thereby encouraging or facilitating residential dispersion, which, in turn, has provided incentives for industry to follow. For a small sample of SMSAs, Steinnes (1977) found that both manufacturing and service jobs followed household location. Such interactions severely hamper any attempts to measure the performance of alternative transportation strategies in terms of economic development, particularly on the basis of cross-sectional data alone.

Policy Opportunities and Information Needs

Current Guidance

The current understanding of the interactions between transportation policies and economic development offers little guidance in the macro-level allocation of transportation investments. Much of the research is based on a normative approach to the problem, stipulating that industries "must" respond to changes in the transportation system that alter the transport cost structure. For any number of reasons, industry may not respond to these changes, respond only indirectly, or may in fact induce more significant changes through technological innovation.

This situation has long plagued development planning in less developed countries where maximizing the economic development impacts of any infrastructure investments is imperative. Early efforts to channel development into certain regions through a speculative improvement of its infrastructure met with rather limited success. Infrastructure development, including the expansion and improvement of a region's transportation system, has become part of an integrated approach to development. Investments in social overhead and investments in directly productive assets are examined within a common framework.

In a country like the United States, such an integrated approach becomes infeasible. However, the exploration of strategic policy issues in transportation in relation to new policy initiatives aimed at economic recovery is not necessarily stymied. Many of the relevant economic changes are exogenous to transportation, triggered by technical change, fiscal and regulatory policy changes, or shifts in product or factor markets. We may lack the knowledge to fine-tune the allocation of transportation investments to promote the right kinds of industry in the right kinds of location--in line with other public policy objectives. But we can examine the broad compatibility of transportation investment patterns and prospective industrial and socioeconomic development under alternative approaches to economic recovery.

Some exploratory work in this direction has been undertaken. Fauth and Gomez-Ibanez (1980) argue that none of the foreseeable trends in economic and population growth or their spatial distribution would necessitate any major shifts in the allocation of transportation investments. SG Associates and the Urban Institute (1980) sketch the potential magnitude of inter- and intra-regional employment and population movements that may alter the parameters for transportation investment policies. However, the evidence presented can only be regarded as preliminary. Further work in this direction is needed.

Information Requirements

Further work exploring the implications of socioeconomic trends for transportation policy should focus on two issues:

1. The relative magnitude of changes in interregional commodity flows associated with alternative industrial development patterns and shifts in freight transportation.

2. The implications of alternative job location shifts linked to different industrial growth paths, especially for private as well as public passenger transportation in urban areas.

So far, the main focus for responses to changing industrial conditions has been the subnational, particularly the state level. State transportation policies (such as upgrading or maintaining existing facilities, or adding to them) are sometimes addressing explicit objectives of industrial development programs.

Examining the implications of new policy initiatives aimed at stimulating economic recovery, or of major exogenous changes affecting industrial growth for transportation policymaking requires a spatial perspective. The information requirements can be delineated in a series of questions:

- What are the implications for regional growth and decline of sectoral growth patterns at the national level associated with different paths to economic recovery?

- What are the resulting interregional commodity flows and activity levels in the transportation sector by mode?

- How do these patterns compare to the current situation?

- What are the job location shifts associated with different regional growth patterns?

- Within regions, how would job locations shift among central cities, the remainder of metropolitan areas, and non-metropolitan areas? Among different size cities?

- How do projected population redistribution trends relate to the likely job relocation patterns?

- What are the major trends in urban travel associated with the different development across and within major regions?

- *How do these trends relate to current patterns? How significant are the changes?*

These questions illustrate the overall scope of the required analysis. A comprehensive view across industries, regions, and transportation modes is essential to explore the possible implications of an economic recovery program for macro-level transportation policy choices.

Such an analysis would also provide a basis for examining the sensitivity of investment allocation decisions to other changes in the transportation system. For example, the current reassessment of subsidy policies in transportation, and the increasing emphasis on user charges are likely to alter the nature of existing linkages.

Finally, answering these questions is important not only for the transportation policymaker. It can also contribute to the assessment of the net costs of different approaches to economic recovery, at the regional level as well as in the aggregate. For example, Burggraf (1980) echoes an often-heard argument that certain economic policy approaches may entail substantial social costs in terms of altering the regional distribution of the infrastructure--having to expand and improve the social overhead capital in rapidly growing regions, while that of declining regions is used far below capacity. A better understanding of the relative magnitude of changes may make for a better appraisal of this and related arguments in the formulation of overall policy approaches.

Possible Approaches

The assessment of relative changes in interregional commodity flows resulting from different industrial growth patterns presents few conceptual problems. The first step involves the exploration of the regional implications of alternative sectoral growth patterns at the national level. For the purposes of a rough exploratory analysis, derived projections of regional growth by sector could draw on a fairly well-developed tool box designed to examine the regional implications of national growth. Many of the simpler methods used some form of shift-share analysis; the strengths and weaknesses of this approach have been examined in a recent review by Stevens and Moore (1980). Data on the association between industrial output by sector and region and activity levels in the transportation sector by mode should be sufficient to explore the broader impacts on interregional commodity flows. More detailed estimates of these impacts may well exceed the needs of the kind of policy assessment suggested here.

The analysis of the implications of alternative sectoral (and thereby regional) growth patterns for private and public urban passenger transportation presents a more complex set of issues. The interaction of job location shifts, residential redistribution, household formation, and economic behavior that shapes urban passenger transportation demand is a complex process. The complexity is reflected in the available evidence on recent trends in the redistribution of employment and population. For example, while major urban centers (central metropolitan counties with a population of 2 million or more) have been losing jobs over the last decade or so, the trend for smaller urban areas is less clear. Thus, we find not only a redistribution of jobs between metropolitan and non-metropolitan areas, but also among different size categories in the metropolitan group.

Given this complexity, a detailed microanalytical assessment of urban transportation demand changes may not be feasible. Fortunately, the level of detail needed for a broad policy assessment again is quite limited. Therefore, simple measures of association between travel patterns and household characteristics may be sufficient to explore the questions listed above.

Summary and Outlook

Our understanding of the interactions between transportation investment policies and economic development is too sketchy to allow for deriving any firm performance criteria from economic policy goals (or the likely outcomes of economic recovery efforts). In the aggregate, the transportation infrastructure of the United States is too ubiquitous to offer much room for contributing to increased efficiency through a suitable allocation of investments. However, at the regional and subregional level, changes in freight and passenger transportation may require a reassessment of investment patterns. A spatial perspective suggests that transportation policies can play a significant role in accommodating changing demands associated with changing residential and industrial location patterns. The discussion here has suggested some questions that can be answered, at least in part, with readily available data. Such answers would be sufficient to outline the major parameters of a transportation policy responding to socioeconomic development trends. Although more responsibility for transportation infrastructure investments is shifting to subnational governmental levels, a comprehensive view can be useful in establishing an overall framework and identifying any possible problems.

In addition, though, further analysis of the interactions between the allocation of transportation investments across regions and across modes and inter- and intra-regional industry growth patterns is required. The main priority for this research should be the national scale, that is, relationships between spatial characteristics of economic growth and the full spectrum of transportation policies. The explicit consideration of the spatial dimension in this analysis will not only provide improved guidance for transportation policymakers, but would also add to our understanding of certain economic policy approaches with significant regional impacts.

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TRANSPORT AND ECONOMIC COMPETITIVENESS

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Abstract

The problem of economic competitiveness and transport activities is apparent at two levels. On one level it is concerned with the question of how to assess the productivity of enterprises in the transport sector; and, on the other level, it is concerned with how to assess to what extent the supply of transport, as an item of intermediate consumption, matches the requirements of industrial enterprises. The latter level involves the need to put transport in its proper focus (that is, its socioeconomic environment in order to understand clearly the two concepts, productivity and surplus).

This paper will deal with:

- the Methodological Basis illustrated by a case study (S.N.C.F. = French Railways);
- the Competitive Economy and Transport Activities with an investigation into the Productivity of Transport Undertakings and Transport in Commodity Trade. The main points to consider are productivity and the weakness of demand, to which a new dimension must be added to overall input productivity so as to reason in terms of competitiveness, namely, the adjustment of supply to demand;
- the Adaptation of Transport to Changes in Economic Relationships requires an effort to integrate existing systems, an effort involving less rigidity, thanks to less State control: Liberalism and Economic Responsibility, but also an Integration in the Transport Chain and Adaptation of Enterprises and Recourse to Innovation.

In conclusion, investment in capacity is not the only mainspring of progress in transport and the slowdown in growth need not lead to renewed immobility in this sector, but should lead, on the contrary, to renewed dynamism enabling transport to continue its contribution to improvements in economic competitiveness.

Introduction

The large transport investment programmes connected with economic growth and the growth in motorisation made it possible to achieve substantial gains in productivity from 1960 to 1975.

Since then, the oil crisis, the slower if not zero rate of growth, financing difficulties, and a slackening in travel demand have slowed down investment to the point that this driving force behind productivity gains is no longer effective and is no longer sufficient to ensure progress in transport.

Today, however, more than ever, Western countries are faced with the need to have competitive economies, if only to protect their balance of payments in face of the considerably increased burden of their oil bills. Consequently, it is necessary to have a better grasp of the relationship between transport and economic competitiveness. Hence, this requires a thorough understanding of how the complex chain of those involved in providing transport services functions.

The problem of economic competitiveness and transport activities is apparent at two levels. On one level, it is concerned with the question of how to assess the productivity of enterprises in the transport sector, and on the other level, it is concerned with how to assess to what extent the supply of transport, as an item of intermediate consumption, matches the requirements of industrial enterprises. The latter level involves the need to put transport in its proper focus (that is, its socioeconomic environment in order to understand clearly the two concepts, productivity and surplus).

This paper will deal in turn with:

- the methodological basis illustrated by three case studies,
- economic competitiveness and transport activities, and
- the adaptation of transport to changes in economic relationships.

The Methodological Basis

Accounting surpluses were calculated for two reasons. The first, to develop a method of measuring strictly and fully the efficiency of business management, led to the creation of an "index of the overall productivity of inputs" in the early 1960s. The second, expounded mainly by Mr. Pierre Masse (Les Dividendes du Progres, 1969/Dividends of Progress), was to try to ascertain the relations which must exist between changes in an enterprise's performance in payment for its inputs and in the prices charged to its customers.

Since its establishment in 1966, the C.E.R.C. (Center d'Etude des Revenus et des Couts/Study Center of Income and Cost) in France has been studying these questions and trying to make the above instruments usable. In 1969 it published the conclusions of its first studies on the S.N.C.F. (French National Railways).

When measuring changes in the economic performance of an enterprise and in the earnings and prices connected with that performance, one must consider all of the inputs which go to produce its output and have to be paid for, including the customers from the list of those who may benefit from progress made by the enterprise. Labour productivity by itself is of limited significance and can be misleading at the enterprise level or even industry level.

In addition, in order to assess the influence of transport on the competitive strength of products, one must not only study the productivity of transport undertakings but must also examine how the transport chain operates as a whole. This can be done by accounting surpluses which are intended to reveal the interaction between the different economic transactors involved in transport activity.

Thus, in moving from the simple to the complex, four concepts have been invoked:

1. the productivity of labour,
2. the overall productivity of inputs,
3. the accounting surplus and the distribution of benefits, and
4. economic competitiveness and the efficiency of the transport chain in responding to industrial demand.

A brief definition of these concepts follows.

The productivity concept is simple in the case of an elementary activity which uses only one input--hours of work--to make a single product. The problem becomes complicated when the activity studied uses several inputs to make several types of products. For example, let us calculate:

- a volume index[1] for production which shows the growth from one period to another in the value of output as expressed in accordance with one invariable price system;

- a volume index for input consumption which shows the growth from one period to another in the value of all inputs consumed as expressed in accordance with the same invariable price system.

The ratio between these indices will provide an index of growth in the "overall productivity of inputs" and the rate of this productivity will be equal to the amount by which the ratio exceeds unity.

As the price system adopted for evaluating production in one period and the following period must be the same, the prices chosen will usually be those for the starting period. The volume index is calculated at "constant prices." The increase in profit at constant prices is called the "surplus," and indicates the extent of profit increase if prices had not varied. In practice, prices in year two are not the same in year one, and the effects of their variations will have distributed some or all of the increase in wealth between the parties involved, that is, customers, personnel, suppliers, entrepreneurs, etc. If, however, there is monetary erosion, a false idea of this share-out will be obtained unless one reasons in terms of purchasing power.

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[1] The "volume" is the sum of the quantities weighted by the unit prices.

The need to work "in constant francs" to see how the surplus (calculated "at constant prices") has been distributed, already introduces a complication, and a second complication is created by the corrections which have to be made to the "fixed assets charges" to allow for the distortions they have undergone owing to inflation. It is well known that the calculation of depreciation is distorted by the refusal of the tax authorities to allow valuations to be revised, so that one has to work out what the fixed assets charges would have been if there had been no monetary erosion. The often unrealistic nature of depreciation accounting, which depends more on fiscal than economic considerations, is a real obstacle to the use of accounting surpluses.

The following formulas sum up the foregoing points:

Let p and f be the prices of the outputs and inputs in year one, and P and F the quantities of the various outputs and inputs.

The overall productivity surplus is by definition

$$S = \Sigma p \ \Delta P \ - \ \Sigma f \ \Delta F.$$

The sum of the "benefits" acquired (which may also be disbenefits) by the various parties involved at the turn of the first year may be measured by the expression

$$A = \underbrace{\Sigma (P + \Delta P) \ (-\Delta p)}_{\text{sum of benefits to customers}} \ + \ \underbrace{\Sigma (F + \Delta F) \ (\Delta f)}_{\text{sum of benefits to inputs}}$$

The accounting surplus shows the connection between productivity and benefits, because the basic accounting equation which sums up the enterprise's operating account for the first of the two years considered is

$\Sigma p \ P = \Sigma f \ F$ and for the following year is
$\Sigma (p + \Delta p) \ (P + \Delta P) = \ (f + \Delta f) \ (F + \Delta F).$

By "developing" the two terms this may be written

$$\left[\Sigma_p P - \Sigma_f F\right] + \left[\Sigma_p \Delta P - \Sigma_f \Delta F\right] = \left[\Sigma (-\Delta p)(P + \Delta P)\right] + \left[\Sigma \Delta f \ (F + \Delta F)\right]$$

This leads to the fundamental relationship: $S = A$.

The total available surplus (that is, the amount of "resources," to use the classical language of national accounting) is equal to the distributed surplus called "uses" in national accounting.

When the benefits are negative, one transfers the negative terms to the first part of the equation (making them positive) and calls them a "heritage," or contribution due to a surplus, giving the equation:

Productivity surplus + Contributions due to a surplus (or heritage) = Sum of distributed benefits

We shall now give an example of how accounting surpluses are applied.

S.N.C.F.

In 1969 the C.E.R.C. concluded that a lasting solution to the difficulties encountered by S.N.C.F. should be sought through increases in productivity. Rail transport, being an activity yielding "increasing returns to scale" and using an infrastructure with reserve capacity, could prove cheaper, in some cases, in the future for the community than other modes which are presently more competitive, but whose development costs and energy expenditure externalities and social costs would be very heavy. Productivity gains would be obtained mainly by economising in inputs. Considering the high proportion of expenditures on personnel in the value of the S.N.C.F.'s output, interest focuses mainly on the trend of the volume of labour. In this connection, the pattern of expenditure in 1978 is relevant, namely, personnel 59%, energy 3%, depreciation and financial charges 13%, and supplies, external services and taxation 25%.

Since the output of the railway system is highly dependent on its infrastructure, on the programming and management of its services and to a lesser extent on the traction of its trains, the only satisfactory approach is a global one--global meaning that it covers all the different modes of transport.

The result of the continued policy of automation and spread of electrification is that for a given level of traffic the trend of increasing returns to scale keeps going up. The degree to which expenditures can be adjusted to traffic is considerably less than it was when the C.E.R.C. made its first study. This also means that any extra traffic can be absorbed at low cost.

Nevertheless, the overall productivity concept raises problems of interpretation connected with the fact that the pattern of activities changes over time and that the cost structure of a given traffic mode is affected by:

- changes in the geographical pattern of traffic;
- changes in traffic distribution over time (the seasonal, weekly, and even daily peaks in passenger traffic are becoming more and more pronounced);
- the extent to which the two sets of previously mentioned factors unbalance traffic (more marked in the case of freight than of passengers).

From 1970 to 1978 the overall productivity surplus and personnel productivity measured in traffic units weighted by employee or employee-hour followed parallel trends. During that period, however, the trends were very irregular. From 1970 to 1974, when traffic increased steeply, progress was made. (Overall input productivity improved by 4.6% per year.) Then in 1975, productivity declined (-4.7%) because freight traffic fell sharply; after 1975, it rose again, but more slowly (+3.1%) from 1975 to 1978, mainly because traffic increased more slowly. Variations (up or down) in the volume of output from one year to the next influence the rate of surplus, whereas reductions in the volume of inputs work through more slowly. Improvements in the level of service, especially passenger train speeds, of course, contribute to productivity gains.

The Competitive Economy and Transport Activities

One is inclined to think that productivity can be bought; people are urged to increase their investment in volume terms as if investment were an end in itself. One forgets, however, that the quality and not the quantity of capital investment counts, and every wrong investment chokes the enterprise a bit more with the burden of its depreciation, which increases costs and reduces margins. The quality of investment is connected with the lowering of barriers to innovation, (among which should be mentioned the artful ways of not letting suppliers really compete with one another thanks to such detailed specifications that only one supplier can meet them) to patent pools and to industrial rings for which there is only one valid spokesman.

Productivity of Transport Undertakings

The productivity of labour is closely connected with the productivity of capital and with improvements in business management.

The productivity of the personnel of the major public transport undertakings (S.N.C.F., R.A.T.P., Air France and independent port authorities) is increasing rapidly, since the indicators show an annual growth rate of between 3% and 7%. The productivity of labour is closely connected with the productivity of capital and with improvements in business management, but the size of the networks which the major public transport undertakings are required to operate is a great handicap to their productivity. This applies both to the S.N.C.F., whose network has a widely varying traffic density, and to the country's airline coverage. About half the internal airlines run by regional transport undertakings can only survive due to subsidies from local authorities and the D.A.T.A.R. (Delegation a l'Amenagement du Territoire et a l'Actio Regionale/Administration of Physical Planning and Regional Action).

In other transport undertakings and especially in road freight transport, personnel productivity rose by about 7% per year in the 1960s, but much more slowly in the 1970s, and it would seem that the gains to be expected in the future will be modest compared to what they were in the past. The same applies to inland waterways which can expect only small productivity gains in the near future.

An analysis of transport costs shows that in the next few years the transport sector is not likely to slow down the rise in the general price index. An analysis of the productivity of transport undertakings could be made only by means of partial approaches. It revealed the need to seek new productivity gains not only in the use of equipment, but also in the overall operation of the transport chain and transport networks.

Transport in Commodity Trade

Competitiveness has become a problem because of the foreign trade deficit. The latter is readily ascribed to unfavourable rates of exchange or to insufficient investment, or else to declining demand in times of crisis.

The main points to consider are productivity and the weakness of demand, to which a new dimension must be added to overall input productivity so as to reason in terms of competitiveness, namely, the adjustment of supply to demand. One of the factors in the competitive power of products is the adjustment of transport to users' requirements; to assess it, one must relate transport sufficiently close to the economic activities for which it constitutes intermediate consumption.

The proportion of transport costs in total intermediate consumption is difficult to calculate, especially due to the large extent to which enterprises provide their own transport services, an occurrence not shown separately in the national accounts. However, the proportion may be estimated at 10% at least of total intermediate consumption. In order to make a better assessment of the economic role of transport, transport must be related close enough to different forms of economic activity; however, this cannot be done at present because the statistical nomenclature for transport does not match the product nomenclature used by the I.N.S.E.E. (Institut National de la Statistique et des Etudes Economiques/ French National Institute for Statistics and Economics Studies).

Adaptation of Transport to Changes in Economic Relationships

Historically, every transport mode has been constructed around a technique and has created its market with the installations and organisation most favourable to that technique. The result is a system distinguished by structural rigidity and not based on an overall analysis of demand nor designed to satisfy the latter in the optimum way. Admittedly, great efforts have already been made to overcome this rigidity, but much remains to be done.

An effort to integrate existing systems is needed--an effort involving less rigidity, thanks to less State control and decentralisation of responsibility at the enterprise level.

Liberalism and Economic Responsibility

The State should only act through a set of measures which enable concerned economists to act in the interests of the community. A transport policy can only be progressive and can only be framed in cooperation with transport operators. Decentralisation will ensure that the whole system functions flexibly. It should be designed to benefit decisionmaking centres pursuing as much as possible homogeneous socioeconomic objectives to facilitate the adjustment of supply to demand.

One field which still retains its inherited rigidity is that of combined transport. The mobile freight box, which is both an instrument of combined railroad transport and a real land-transport container, seems to have a rosy future, but the problems connected with the rates charged for carrying it by rail should be settled.

Another sector which suffers from the weight of the past is inland water transport. It is still governed by a particularly paralysing act which is still strongly supported by barges. A move towards more liberalism in this sector is considered very desirable.

The social problem which these measures might raise would boil down to retraining a few hundred skilled personnel and should not be an obstacle to reform.

Freight transport by road also suffers from the weight of long-standing regulations known as "transport coordination" and consisting of a compulsory road freight rate system (T.R.O.) with upper and lower limits, together with a system of quotas for road transport capacity. These measures were taken in the 1930s to protect rail transport.

Some shippers are asking for the T.R.O. to be made more flexible or even abolished, but the carriers want to keep it. A move in this direction can be envisaged, but it should be cautious, gradual and carried out in stages without giving up the framework of controls now in force. Indeed, it is essential for the authorities to retain the means of combating factors which disturb the market (distortion of competition and dominant positions) and the means for preventing the deterioration in the quality of service which might result from such a move.

The problem of operating unduly large networks calls for certain measures, but caution is necessary and loss-making services should only be supported for a limited period (provided that they will eventually prove profitable) and follow a thorough study of the regional and national interests they serve.

First, regarding the railways, it would be desirable to list the lines which are indispensable for good regional development and work out arrangements whereby the regions might be able to guarantee to operate other lines which are only of regional or local interests. Lines which provide transit between regions and those which penetrate far into hilly country (although carrying little traffic today) should not be closed down. These lines are necessary for the economic competitiveness of the country which is dependent on the economic competitiveness of the regions.

Secondly, the healthy and balanced development of internal air transport is dependent on discouraging the tendency towards more and more air links by concentrating the entire network of the country's air services on a certain number of regional airports (about thirty) and by devising fast and flexible land-borne feeder services between the peripheral towns and the regional airport (regular shuttle services and shared taxis).

Integration in the Transport Chain

With the development of trade and the increasing complexity of the operation of the transport chain, more and more importance is attached to the function of "transport organiser." This function is performed by a transport auxiliary--either the shipper himself or a carrier. It seems desirable to widen this function by involving it more closely with the commercial side of industrial enterprises.

The S.N.C.F., for example, whose commercial policy is becoming increasingly important, is developing a "marketing" type of approach and even a policy of freight transport "products" better suited to shippers' demands (fast light trains from point to point, customers' open supply, etc.). In a context of decreasing barriers between modes of transport, it would also seem desirable for the S.N.C.F. to be able to provide a complete logistical service.

The independent port authorities are another example. Here, it would be desirable to require enterprises working in ports, especially cargo-handling enterprises, to advance from the stage of mere suppliers of services to the stage of industrial enterprises. This could be done by urging them to take a share in investing in the equipment for the ship's berths where they operate and by giving them a direct interest in the profitability of publicly-owned works and plants.

Transport undertakings tend to be divided into two groups--those which control the freight traffic and have the capacity to market the services they supply and those which are increasingly confined to the role of hauler and do not have the means of marketing their transport capacity. It would be desirable to induce principals and subcontractors to redefine their business relationships by encouraging them to develop contractual ties over long enough periods to amortize equipment at prices which reflect costs.

Transparency is one of the conditions for the proper operation of a market subject to the rules of competition. The small and medium-sized enterprises (P.M.E.) are the main victims of the lack of transparency at present maintained by certain transport auxiliaries. However, in trying to clarify the definition of the service rendered by transport auxiliaries, the trade has already taken the initiative in publishing a code of ethics and a nomenclature of services supplied; these steps should be followed by drawing up "standard contracts" and publishing a clear statement of the fields in which the various auxiliary enterprises specialise.

Improvements in the competitiveness of transport undertakings depend on research and development.

Adaptation of Enterprises and Recourse to Innovation

There is no doubt that special attention should be given to organizational innovation--with the development of data processing, a vast field of research and study which has much to contribute to transport--and to improving the conditions of supply of transport which is better adapting itself to demand due to the appearance of "new products."

Technological innovation concerns mainly the sector up stream--the transport equipment industry, building contractors, etc.--although the impact of modern methods of traffic control is far from negligible in improving the efficiency of transport undertakings.

In France the manufacture of private cars has by and large reached a high standard of international competitiveness and has captured nearly one-third of the European market and over one-tenth of the world market. The commercial vehicle industry is in a distinctly less enviable situation, and the market for industrial vehicles of over six tons authorised total laden weight has been stagnating for ten years. Meanwhile, the railway equipment industry at present ranks high among France's export industries, but its main customers in France (S.N.C.F. and R.A.T.P.) have now completed the programs for modernising their rolling stock. In addition, there is the added factor of increased competition in international markets. Moreover, France is still the second largest world exporter of building and constructional works, although results have been less brilliant in the last few years. Research work should, therefore, be stepped up in this area.

Motor vehicle research should continue to place priority on the problem of reducing unit consumption, and it should be possible to supplement official policy with assistance to research, taking into account the results which manufacturers undertake to obtain.

The manufacture of railway equipment raises a specific problem connected with a buyer's monopoly situation. Wherever innovations are made, the national railways have wide decisionmaking powers regarding the equipment to be used.

In this field, the present situation in national and international markets raises the question of whether there should be international cooperation, particularly between European countries, since it seems to be an indispensable condition for the long-term survival of the railway equipment manufacturing industry. Furthermore, regarding foreign markets, it is necessary for firms exporting expertise to be able to adapt themselves to the problems which arise abroad without seeking to impose the arrangements in force in their own countries, and for equipment to be made which is suitable or easily adaptable for export.

In the building and construction sector, exporters are concentrating their efforts on goods and services with a high technology content which affords better protection from competition with developing countries, such as technical assistance and complex projects. No new growth stage seems possible in this field, however, unless new enterprises enter the export market.

Conclusion

In conclusion, investment in capacity is not the only mainspring of progress in transport and the slowdown in growth need not lead to immobility in this sector, but should lead, on the contrary, to renewed dynamism enabling transport to continue its contribution to improvements in economic competitiveness.

REFINING THE POLICY OBJECTIVES FOR EVALUATING URBAN MASS TRANSPORTATION INVESTMENTS' ECONOMIC DEVELOPMENT IMPACTS

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Abstract

This paper indicates the types of broad policy expectations which have been identified with potential transportation investments in the urban U.S. It also reviews the limits which should have governed those expectations. Finally, the empirical evidence of the economic development impacts of urban mass transit investments in the U.S. is summarized.

The conclusion of this author is that urban mass transit investments have not met expectations in terms of economic development impacts. Yet the reason may be that the policy objectives were ill-conceived. The paper offers some questions which refine the definition of policy objectives. Some of the questions may represent implicit objective statements which are far more specific than broader interests in stimulating "economic development." Each of the questions suggest the opportunity to develop supporting policies which would allow a transportation investment to achieve at least some of the economic development objectives expected of it by policymakers and public decisionmakers.

Introduction

The purpose of this paper is to raise the types of questions which should be considered in evaluating a potential public transportation investment in a mature urban area when justification for public investments includes their implications for economic development. The policy issues or implications are drawn from recent experience in the United States where beneficial economic development impacts have been cited frequently as a justification for major public investments in urban mass transit projects. To this extent, the issues raised and the policy context used to illustrate the possibility of misleading evaluation are unique to a mature and urbanized society; nonetheless, opportunities for generalization exist. By raising the specific questions which can guide the evaluation of transit investments in the United States, within the specific policy context of that country's economic and development objectives, it may be possible to illuminate both the types of evaluation measures and the types of supporting policies which may be necessary elsewhere to formulate transportation investments which reinforce desired economic development consequences of transportation investments.

This paper describes the policy context in which transportation investments are made, a context which suggests the importance of economic and development impacts in the decisionmaking process. It then formulates an analytic framework and a series of policy questions which define the extent of the contribution economic and development impact analysis can make to the choice among alternative transportation investments.

In order to avoid ambiguity, the term "economic development" has not been used in the following discussion. In the past, some have used the term "economic development" to imply private sector investment in the urban development of a region in response to a transit investment. Most U.S. agencies, on the other hand, consider "economic development" to involve the development of employment or business activity which may or may not have physical urban development ramifications. Although this paper deals with the impacts relevant to either interpretation of the term, "economic impacts" have been defined as the effects of the transit investment on urban real estate development and land use.

The approach used in this paper is to provoke consideration and discussion by posing questions--without answers. It is hoped the questions will frame a refinement of the traditional economic development expectations from transportation investments. The questions certainly suggest, independent of the broader policy objectives, the types of objectives which can only be met by refining the objectives to the point where direct policies can be implemented to reinforce the desired impact of transportation investment.

The Context of United States' Policy Objectives for Transportation Investment During the 1970s

During the 1970s, interest in investing in urban mass transportation in the U.S. was most frequently described in a rhetoric concerning urban revitalization and economic development. It appeared that these potential benefits of improved transportation were seen as a natural consequence of transportation investment among many planners who observed the economic activity and development patterns of cities with well developed transportation infrastructure. These benefits also appealed to public decisionmakers who sought public support for the local financing requirements of transportation investments.

The economic and development impacts of major urban mass transportation investments in the United States have had to be considered under several implicit United States Federal legislative mandates which were in force during the late 1970s. The Federal mandates are important since, in the United States, local urban mass transportation improvements are eligible for up to 80% Federal subsidy. The policy objectives become important since Federal funds are limited; some criteria must govern their distribution.

The fundamental mandate for evaluating the economic implications has been the National Environmental Policy Act (NEPA) of 1969, Section 102(2)(c), which requires that all Federal administrative organizations investigate the environmental impact of proposed Federal actions. An environmental impact, *per se*, has been interpreted as the impact of a proposed action on the natural environment and the economic or social environment.

During 1978 and 1979, the Secretary of Transportation made three formal policy statements articulating national aims and objectives that bear on the economic and development impacts of major transportation investments.

On February 6, 1978, Secretary Brock Adams presented "A Transportation Policy for a Changing America" which emphasized the broader concerns that are relevant to evaluating a transit investment. This statement defined a variety of goals including:

- improved allocation of human and material resources, including increased minority and female employment in transportation and greater access to jobs for unemployed persons without automobiles;

- conservation of energy to reduce dependence on scarce fuels; and

- improved transportation productivity.

On March 7, 1978, the Secretary and the Urban Mass Transportation Administrator issued a joint statement clarifying the Department's policy toward urban rail transit investment. The "Policy Toward Rail Transit" indicated that preference would be given to those metropolitan areas which view rail transit investment as part of a long-term regional strategy to promote urban economic development and orderly patterns of metropolitan growth. Local jurisdictions were required to provide evidence of supportive policy designed to enhance the proposed transit system's prospect for economic viability.

Again, on February 13, 1979, in elaboration of the aims established a year earlier, the Secretary announced a variety of objectives for Federal transportation investment that focuses specifically on economic and development effects:

- to support the general revitalization of central cities, particularly by taking advantage of joint development opportunities;

- to assure that persons and communities adversely affected by projects also share in the benefits of the investment, by setting aside shares of contract expenditures and jobs for the participation of a community's minority or disadvantaged population and the unemployed; and

- to discourage the waste of scarce fuels which can result from urban sprawl and automobile commuting over long distances.

During the same period, the Administration was also articulating a formal policy concerning the Federal role in the growth and revitalization of cities.

In March 1978 the President announced his national urban policy. This initiative was designed to achieve four objectives:

1. to preserve the heritage and values of our older cities;

2. to maintain the investment in our older cities and neighborhoods;

3. to assist newer cities in confronting the challenges of growth and pockets of poverty in a fair and equitable manner; and

4. to provide improved housing, job opportunities, and community services to the urban core, minorities and women.

These objectives were to be achieved through the implementation of ten Federal policies, each of which bridges the traditional functional area of any one cabinet department. Four of the policies, however, were particularly relevant to transit investment decisions and their economic and development implications:

1. "The Federal Government will help expand business and job opportunities for the urban core and minority men and women. Federal programs will seek ways to increase the mobility of the growing number of men and women trapped in poverty or dead-end jobs." To accomplish this, the Administration proposed a strategy which includes the provision of improved transportation access to decentralized jobs.

2. "The Federal Government will offer strong incentives to businesses and industries to remain, expand, or locate in the economically troubled cities. To the extent possible, Federal disincentives for locating in troubled cities will be ended." A package of financing incentives to stimulate private sector investment in distressed cities was called for among the strategies proposed to promote this policy.

3. "The Federal Government will help make troubled central cities attractive places to live and work. It will help improve the range and quality of decent social services available to their residents...." Among the strategies proposed to promote this policy is the use of transit investments as incentives to leverage private urban revitalization activities and related actions in pursuit of economic, environmental, and social goals.

4. "The Federal Government will help cities develop efficient land settlement patterns. Federal laws and programs will be amended to discourage sprawl and encourage energy efficient and environmentally sound settlement patterns in urban areas." To accomplish this, the urban policy proposes to account for land development impacts in Federal grant decisionmaking and to favor projects supportive of compact community development.

In response to the Urban Initiatives Program developed to carry out this urban policy, on October 12, 1978 UMTA announced its commitment to direct its grants toward projects that will:

- provide employment opportunities, primarily in private businesses, to the long-term unemployed and disadvantaged in urban areas;

- incorporate, to the maximum extent feasible, investments by private enterprise that strengthen the economic base of a distressed community, including investments in commercial and residential development;

- contribute toward urban economic development;

- provide increased access to employment for the economically disadvantaged; and

- achieve an areawide comprehensive strategy which is intended to provide a broad range of economic development opportunities in the economically disadvantaged areas of the community.

Other broad Federal economic policy with a bearing on major urban transit investment has not been articulated so directly in relation to transportation and urban development objectives. The most important of these general economic objectives are the twin macroeconomic objectives of stimulating business activity (or aggregate employment and income) and controlling inflation. Although major transit investments have not been designated explicitly as a tool of macroeconomic policy in the way that general public works aid has been, the analysis of transit proposals may have been considered in terms of possible stimulative or inflationary effects.

Types of Economic and Development Impacts

Given the strong policy interest in transportation's role in economic development, it would seem important to review the theoretical basis for these frustrated expectations. What are the possible economic and development impacts, why did they not materialize, and how might one have refined either the transportation investment or the definition of the objectives to assure their satisfaction? A subsidiary issue, which is not treated here, is the matter of the measurement or prediction techniques which may suggest economic and development impacts that are meaningless in the context of the true objectives.

The economic and development impacts of major urban mass transit investments result from a complex series of interactions in the characteristics which comprise the theoretical economic market: labor, materials, capital, real estate, and consumer services. Given the complexity of an urban economy and the importance of transportation to the geographic distribution of people, buildings and activities, the potential impacts of major changes in the transportation system are many and varied.

In simplified form, however, the potential economic and development impacts may be grouped and viewed, as shown in Figure 1, as stemming from the two most obvious and direct changes involved in transit investments, which are:

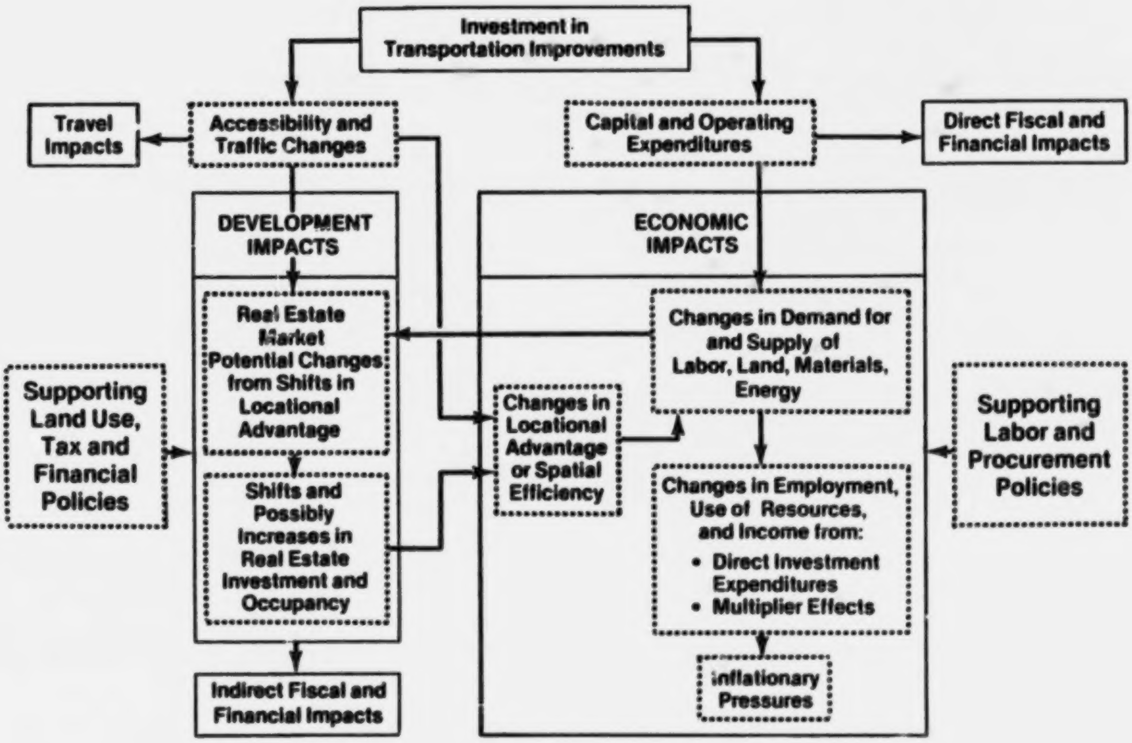
1. The expenditure of money for the labor, materials, machinery, and land that are used in the construction and operation of a transit system; and

2. Changes in the time and money costs of travel because of the new services or facilities provided.

The changes due to expenditures have their greatest effect on employment and the production of goods and services. These impacts are treated as economic impacts in this paper. Changes in the time and money costs of travel affect the relative convenience with which people can reach one place or another within a region. This change in the attractiveness of one location or another manifests itself in the attractiveness of that location for development. Hence, it is treated as a development impact.

FIGURE 1

POSSIBLE ECONOMIC AND DEVELOPMENT IMPACTS FROM AN INVESTMENT IN TRANSPORTATION IMPROVEMENTS


Investment in Transportation Improvements
Travel Impacts
Accessibility and Traffic Changes
Capital and Operating Expenditures
Direct Fiscal and Financial Impacts
DEVELOPMENT IMPACTS
ECONOMIC IMPACTS
Real Estate Market Potential Changes from Shifts in Locational Advantage
Changes in Demand for and Supply of Labor, Land, Materials, Energy
Supporting Land Use, Tax and Financial Policies
Changes in Locational Advantage or Spatial Efficiency
Supporting Labor and Procurement Policies
Shifts and Possibly Increases in Real Estate Investment and Occupancy
Changes in Employment, Use of Resources, and Income from:
• Direct Investment Expenditures
• Multiplier Effects
Inflationary Pressures
Indirect Fiscal and Financial Impacts

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Even in this simplified "typical" form, the impacts shown in Figure 1 are merely hypothetical ones which may or may not occur on a magnitude warranting consideration; they may not even occur at all. The remainder of this section of the paper will examine these hypothetical impacts more closely, suggesting ways of understanding how and why such impacts may occur, certain characteristics of the impacts that may be important to the analysis, and some of the kinds of questions that may help to relate the impacts to policy objectives.

Economic Impacts

An investment in new transportation improvements, then, creates additional demand for goods and services. This additional demand is satisfied through employment or production. The employment or production, in turn, results in wages or business income. These impacts--increases in wages, production, and business income--are required to make the transportation improvements. As the wages or business income are spent, and as intermediate needs of the production process are purchased, the original impact is multiplied by the additional activity which is stimulated. Together, these direct and multiplied impacts represent the total economic impacts of expenditures on transportation investments as they are defined here.

Additionally, a transportation investment may stimulate changes in the economic geography of the region through travel, development, or environmental impacts. These changes may also add indirect economic impacts. Although the measures of economic impacts appear quite straightforward, they are influenced by a number of considerations which are the subject of this section. The impacts may be viewed from two perspectives:

1. the employment or use of resources, especially of labor; and

2. the payments for the use of those resources, or income.

Although these are two facets of the same process, both are important to the analysis because policy objectives may relate specifically to one or the other.

The analysis of these potential impacts is a process of predicting how the investment is likely to flow into, through, and out of the urban economy. These flows depend on more than the direct changes in demand and supply for the labor and other resources used in transit construction and operation. They also depend on where the resources are drawn from and how the payments for additional resources used--that is, the additional direct income--are in turn used in the economy for further purchases of goods and services that also require the use of resources and the payment of income. The flows of resources and incomes can be an important part of the impact, multiplying the direct impact of the investment repeatedly. There may also be economic impacts only indirectly related to the capital and operating expenditures, such as changes in employment or income--and especially in their disbribution--induced or stimulated by travel, development, environmental, or other kinds of impacts. There are thus three major sources of economic impacts:

1. the direct resource use and expenditure effects of construction and operations;

2. the "multiplier effects" of the flow of direct resource use and income through the urban economy; and

3. the employment and income effects of other kinds of indirect impacts induced by the transportation investment, such as travel, development or environmental impacts.

The techniques used to estimate, measure or predict economic impacts in the past have frequently avoided the important qualifying issues which will relate assertions of economic impacts to policy objectives. Here, a number of considerations in the measurement of economic impacts are related to their adequacy in terms of meeting policy objectives:

- The Definition of the Impact Area,
- Net Impacts: Addition or Redistribution?,
- The Incidence of the Impacts,
- The Timing of Impacts, and
- The Potential for Inflation.

The Importance of Supporting Policies for the Achievement of Economic Policy Objectives

Supporting policies can be important in directing the economic consequences of an investment into patterns which may contribute toward the achievement of policy objectives. Techniques allow the evaluation of the economic impacts in a manner which highlights the opportunities for reinforcing policies. Thus, policies should be recommended as part of an investment program, not as a mitigation measure so much as an enhancement measure.

For instance, decisions to seek employees in particular areas or among particular groups or to obtain equipment or materials from certain kinds of firms or from firms in certain areas (and, especially, statutory or contractual requirements for such actions) may change what would otherwise happen differently. Such policies are of varying effectiveness, and they should be considered carefully in any analysis of economic impacts. For example, a set-aside of some portion of work for minority-owned businesses will likely have an effect on the distribution of business income among racial and ethnic groups but might or might not have any impact on the distribution of wage income because the firm's employees would not necessarily be members of minority groups.

On the other hand, if one were attempting to increase employment in an area of high unemployment, two effective reinforcing policies would be to encourage a "buy local" policy and to accept the consequences of labor-intensive techniques as a substitute for capital-intensive techniques.

Development Impacts

The development impacts so often ascribed to transportation investments could be more accurately described as development opportunities, since transportation improvements merely create more accessible locations. The policy interest in this implication of a transportation investment and the qualitative nature of predictive techniques emphasize the importance of several characteristics which contribute to the interpretive context:

- Geographic Scale for the Analysis
- Net Impacts: Addition or Redistribution?
- The Timing Impacts

The Importance of Supporting Policies for Achievement of Development Policy Objectives

In a theoretical context, the advantages of location with better access to transit--specifically transit stations--should be most attractive to developers. In fact, among the most important determinants of whether or not the market responds to this apparent locational advantage will be the nature of other public policies including zoning. The most dramatic examples of development at transit stations result from the use of land use and zoning policies, tax policy, and other public investment policies which direct growth (or limit growth) to transit stations.

In many countries--certainly in the United States--land use is quite thoroughly regulated by government, so too are the financial markets for real estate. The taxation of real estate can have enormous effects on patterns of use and investment. Furthermore, the space for some uses that can strongly affect the demand for real estate--parks, recreation areas, and most other "public" spaces--is often provided directly by government. In all of these ways, and by direct involvement in stimulation of real estate development as well, supporting public policies can affect the nature and distribution of development impacts. A particularly significant example is that of "joint development," in which space used for the provision of transit services--stations and terminals, for example--may be used jointly for other private purposes with financial participation by both public and private investors.

Empirical Evidence Concerning Economic and Development Issues

A considerable number of studies have been undertaken in pursuit of empirical evidence on the economic and development impacts of transportation investments. Most of these studies in the United States have been attempts, after the fact, to isolate the impacts which can be directly related to the transportation system decision.[1] Although the U.S. Urban Mass Transportation

Administration is currently funding studies which will include documentation of existing conditions before system construction--the ex ante data collection--previous studies have not had the benefit of this analytic foresight. Consequently, the empirical evidence in drawing relationships between transportation investments and the "impacts" are observed after the fact.

The employment impacts are less elusive, since the issues raised are the size of the impact, not the basic causal relationship between expenditures on transportation and employment. The important policy interest in the relationship between transportation investments and development has not been resolved by empirical evidence for a number of reasons.

The relevance of previous analysis or findings to estimating future impacts is constrained by the dramatically different physical and economic environments in which future systems will be built. The earliest transit systems clearly affected development patterns in the pre-auto era. Similarly, the enhancement of auto accessibility--both from increases in auto ownership and improved road systems--allowed and encouraged low density suburban growth. A measure of the impacts of a transportation investment on development during either of those eras does not imply its relevance to development decisions in a mature urban region in an inflationary era of high petroleum prices (and scarcity).

The environment--in the comprehensive sense which includes popular attitudes--clearly affects the development consequences of a transportation investment. Evidence does seem to suggest that an important lever to the effectiveness of a transportation investment in stimulating directed development will be public policies, such as land use policies which reinforce the theoretical impacts of a transit system on land use.

Some Questions Relevant to Policy Objectives

This paper has indicated the types of broad policy expectations which have been identified with potential transportation investments in the urban U.S. It has also reviewed the limits which should have governed those expectations. Finally, the empirical evidence of the economic development impacts of urban mass transit investments in the U.S. is summarized.

The conclusion of this author is that urban mass transit investments have not met expectations in terms of economic development impacts. Yet the reason may be that the policy objectives were ill-conceived. This section offers some questions which refine the definition of policy objectives. Some of the questions may represent implicit objective statements which are far more specific than broader interests in stimulating "economic development." Each of the questions suggest the opportunity to develop supporting policies which would allow a transportation investment to achieve at least some of the economic development objectives expected of it by policy makers and public decisionmakers.

- How will the transit project's net addition to investment in the area affect the area's total amount of economic activity, or gross regional product?

- To what extent are the various alternatives likely to create income in the form of wages and salaries and to what extent in property income?

- How much regional employment will probably be involved directly in an investment in transit or stimulated by the flow of transit project expenditures?

- How much employment will be added or shifted in location to occupy the business real estate development stimulated or shifted by the transit alternative?

- How much demand for labor will probably be added (not shifted) by the development and construction of business and residential real estate stimulated by the transit investment?

- How much of the demand for labor will be temporary (lasting only for the period of transit construction) and how much will probably be sustained?

- Does the demand for labor, which is stimulated, occur in occupations which are available to the current unemployed workforce, the hardcore unemployed, minorities, and women? Or is it likely to be absorbed by overtime employment and immigration of labor?

- Does the demand for labor, which is stimulated, increase accessibility to employment for the long-term unemployed and disadvantaged in the urban core (by bringing job opportunities closer to the unemployed)?

- Are the resource requirements (labor, land, materials, etc.) of the transit investment or the induced development likely to have inflationary impacts because of supply "bottlenecks"?

- Will travel impacts change the accessibility of disadvantaged groups or to existing demand for labor (not related to the transit investment induced development)?

- Are the travel impacts likely to induce any area residents not currently in the labor force to seek employment?

- Are the travel impacts likely to affect the comparative advantage of businesses within the area in a way that will tend to increase area business income or to change the mix or distribution of business?

- Will the transit investment make existing buildings and structures sufficiently more accessible or attractive to satisfy existing unmet demand for space or to attract more productive uses?

- Will the transit investment make existing buildings and structures sufficiently more accessible or attractive to satisfy existing unmet demand for space or to attract more productive uses?

- Will the transit investment's economic impacts create additional demand for space in the area? What kinds? Where?

- To what extent will the transit investment shift the location of demand for space for certain uses? What kinds? From where to where?

- Will changes in the occupancy of existing buildings stimulated by the transit investment reduce the available supply of certain kinds of space for certain socioeconomic groups?

- Does the proposed transportation alternative help the region develop efficient land settlement patterns, shift future growth into the urban core, discourage sprawl and encourage energy efficient and environmentally sound settlement patterns in the urban area?

- Does the proposed transportation alternative reinforce a long-term regional strategy to promote urban economic development and orderly patterns of metropolitan growth?

- How is the character of various neighborhoods affected by existing transportation facilities and proposed ones? Can neighborhood quality be improved by transportation projects and programs? Will encroachment of non-residential uses into residential neighborhoods be arrested or stimulated?

- What opportunities might be created for coordinated land use development as a result of a major transportation investment? How would the results differ from what would occur without the investment?

- Does the transportation investment stimulate growth in an area with excess public service capacity or where increases in public service capacity can occur in a cost-effective, efficient, and financially equitable manner?

- Are the unit costs of serving one land use pattern higher or lower than another? Are there other reasons to prefer one pattern over another?

- Will the occupants of space developed or used differently because of a transit investment find community facilities more or less accessible than they would without the transit investment and resulting development?

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TRANSPORTATION AND URBAN ECONOMIC DEVELOPMENT

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Abstract

During the last decade the Federal government assumed major new responsibilites for transportation and urban economic development. The public role for both functions evolved in response to a crisis situation. Federal assistance for urban economic development was precipitated by massive disinvestment, high unemployment, and the fiscal decline of cities. Public support for transportation was brought about by the bankruptcies of private transportation enterprises. Since then, transportation and urban economic development efforts have rarely been integrated. In the last few years, however, policymakers in both fields have begun to realize the importance of coordinating their efforts for a more effective use of limited public resources. However, research on the role of transportation in urban economic development is limited. Most innovative transportation/economic development initiatives undertaken at the local level have not been documented.

This paper examines some of the ways that transportation and urban economic development can be linked, discusses problems in integrating the two fields, and suggests how additional research can advance the state of the art.

Introduction

Transportation and urban development are inextricably linked; the growth and configuration of cities was largely a factor of their accessibility. The historical relationship between transportation and urban growth has been long recognized by planners and historians. However, the use of transportation investments to stimulate urban economic development is relatively new. Only during the last decade have public policies and programs that support the use of transportation for urban economic development been established. Although policymakers in both fields realize the importance of integrating transportation and economic development functions, few linkages exist between the two disciplines. To date, many opportunities for stimulating economic development through transportation have been missed, and there has been little research on the relationship between the two fields.

This paper, therefore, illustrates opportunities for promoting urban economic development through transportation, examines why the economic potential of transportation has not been fully realized, and suggests how further research could promote greater coordination between the two fields.

Urban Economic Development

During the 1970s, a new discipline called urban economic development emerged in the United States. Established to address local economic problems, urban economic development represented a radical departure from earlier attempts to revitalize cities. Traditional urban planning approaches which used zoning and land use policies to direct development had failed to stimulate new business activity. Chamber of Commerce promotional strategies and industrial attraction programs had been unable to attract new businesses to older central cities and had not been geared to stemming the exodus of businesses from central cities. Specialized Federal assistance programs targeted for severely deteriorated areas, such as the urban renewal and Model Cities programs, had not reversed urban economic decline.

Thus, a new approach emerged. This approach seeks to combine public resources and private investment to bring about structural changes in local economies, helping them shift their dependence from older declining industries to new growth-oriented sectors of the economy. This new discipline is action-oriented and its practitioners concentrate directly on stimulating private investment and jobs by providing direct incentives, such as low-cost financing, tax abatements, low-cost land, and employee training subsidies, when necessary to encourage projects. Although deal-making with private investors is a major concern, economic developers also examine local regulatory tax and other policies to ensure that they are conducive to development.

While urban economic development was evolving, the public sector was taking on increasing responsibility for urban transportation. In addition to Federal subsidization of railroads, municipal governments, also with Federal assistance, were acquiring local independent transit companies and forming public transit agencies.

For both transportation and urban economic development, the public sector role evolved in response to a crisis. Federal assistance for urban economic development was precipitated by massive unemployment, private disinvestment and the fiscal decline of cities. Public support for urban transportation was necessitated by the bankruptcies of private transportation enterprises. Not surprisingly then, policymakers in both fields have concentrated primarily on their own problems; rarely have they interacted.

Recently, however, they have begun to work together to integrate these two functions for a more rational and effective use of public resources. Special Federal policy directives, such as the Urban Initiatives Program, fostered this relationship by providing financing for transportation projects that stimulate urban revitalization.

State of the Art

The use of transportation to foster urban economic development goals is just beginning to be explored at all levels of government. At the local level, transportation and economic development specialists have not examined comprehensively how their two fields can be integrated, nor has much research been done on this topic.

Joint development is the only transportation/economic development linkage to receive much attention to date.[2] Numerous studies have demonstrated the potential of mass transit systems to attract private investment around stations. However, joint development projects around station areas have not always been successful, nor has the joint development potential of transportation facilities been fully exploited. Very often cities have not capitalized on these opportunities because local transportation agencies lack the expertise and legislative authority to negotiate deals with private developers or undertake projects themselves. Yet economic developers who do possess these tools are often excluded from the transportation planning and implementation process.

Similarly, many transit and pedestrian malls recently implemented in declining commercial areas have been less than fully successful. Often circulation and pedestrian improvements were regarded as a panacea for declining retail sales. These design improvements were implemented alone when a more comprehensive strategy was needed, including financial and management assistance to help retailers improve the quality and mix of their merchandise and the appearance of their stores.

Joint development projects and transit malls are the most common transportation/economic development linkages undertaken at the local level. However, cities are beginning to use transportation to stimulate their economies in many other creative ways. The Council for Urban Economic Development, a non-profit corporation committed to revitalizing America's cities, is currently investigating these local initiatives for the U.S. Department of Transportation. Research to date has turned up some interesting examples of creative linkages.

For example, in Portland, Oregon, transportation and economic development specialists worked closely to maintain and improve the economic viability of an underutilized, inner-city industrial area. To increase access to the area, the creation of a municipal vanpool program was recommended. While many vanpool programs are established to serve special user groups, such as the elderly, the handicapped or employees of large private firms, the Portland effort was designed as one of many business incentives used in the overall development strategy for attracting businesses to the area. The use of the vanpools will free land for development that would otherwise have been needed for parking, allow more intensive use of land, and relieve congestion, thus increasing the attractiveness of available parcels. Recognizing the importance of the vanpool programs for business attraction and retention, city staff secured funding for it from a Federal economic development agency rather than a transportation agency.

In Miami, Florida, like most American cities, the central business district (CBD) is relatively empty during weekends and off-peak hours. Although tourism is one of the region's biggest industries, a large number of tourists come to the area and do not visit the central business district. To capitalize on a significant economic opportunity--the approximately 1.5 million cruise ship passengers that pass through the port each year--a downtown merchants association charters buses during off-peak hours and weekends to bring cruise ship passengers from the port to downtown. Although the distance is less than one-half mile and long delays are frequently encountered prior to departures, most cruise passengers did not spend this time in downtown Miami.

In addition to generating sizable retail revenues, the free shuttlebus system may encourage many of these passengers to extend their stay in Miami after their cruise or to return as tourists on another trip. In previous years, most cruise ship passengers had flown into and out of Miami's airport, transferring to the port by chartered bus or taxi without setting foot in the downtown area.

The Port Authority of New York and New Jersey is the largest and oldest transportation agency in the bi-state area. Recognizing that its operations are inextricably linked to the health of the metropolitan New York-New Jersey economy, the Port Authority has introduced economic development criteria into its decisionmaking process. The Port's transportation and economic development staff systematically analyzed the region's transportation needs to identify those investments that will generate the greatest amount of jobs and tax revenues for the metropolitan area. They found the economy is shifting from a manufacturing base to a service orientation, with tourism and related entertainment and international business activities expanding greatly. Recognizing the importance of air travel to these industries, Port planners recommended that the regional transportation improvement program (TIP) give highest priority to airport access improvements. The aviation industry, with its 200,000 associated jobs and importance to commerce, has a major impact on the metropolitan economy.

These examples illustrate just a few of the ways transportation can be used to leverage economic development at the local level. Since this subject has not received much attention by researchers to date, no conceptual framework has evolved that defines the relationship between the two fields or examines the whole spectrum of linkages. Although the list is not comprehensive, these linkages encompass several modes, call for varying degrees of capital investment, and address many economic development issues.

Potential Transportation/Economic Development Linkages

Citywide Development

- Link short-term and long-term transportation and economic development planning.
- Introduce economic development concerns into transportation capital budgetary decisions.

Industrial Development

- Paratransit system for employees of industrial areas to reduce parking space needed, thereby freeing land for plant expansions.
- Paratransit systems to outlying areas to enlarge employer labor pools.
- Paratransit system to transport Comprehensive Employment Training Act (CETA) or other job trainees to relatively inaccessible training and job sites.
- Rail and street improvements in new and existing industrial areas to help retain and attract business.
- Airport Industrial Parks.

Small and New Business Development

- Special attention given to small and new businesses through transportation procurement policies.
- Opportunities for small and new businesses to fill the transportation gaps that may occur as a result of deregulation of rail, trucking and airline industries. For instance, commuter airlines may provide service to cities that have lost commercial airline service due to deregulation.

Downtown Development

- Joint development around rail stations, downtown people mover stations and intermodal facilities.
- Downtown People Movers - increase land for development by reducing parking in CBD, stimulate joint development and property values, and increase market draw.
- Transit mall in conjunction with business development strategy.
- Use of buses during off-peak hours to promote tourism.

Commercial Neighborhood Development

- Paratransit system providing access to commercial district for neighborhood residents.
- Pedestrian malls or improvements in conjunction with management, financial, and marketing assistance to small businesses.

Foreign Trade Development

- Foreign Trade Zones at ports and airports.

- Provide incentives including industrial parks for industries involved in export to locate at an airport or port.

- Construction and modernization of coal port terminals for increased coal exports.

- Help domestic transportation manufacturers become more competitive internationally.

Problems in Linking Transportation and Urban Economic Development

Despite the potential of transportation to stimulate urban economic development, transportation and economic development specialists have not worked closely together. Some of the reasons for their limited interaction are discussed below.

Different Orientations and Organizational Structures

Transportation and economic development grew out of very different traditions. Transportation is rooted in engineering and technology, while economic development evolved from business, industrial, social, and community programs.

Furthermore, policymakers in both fields often have different time schedules and geographic areas of concern. Working primarily on short-term projects (one to three years), economic developers concentrate on central cities or sub-areas of cities. The planning and implementation of transportation projects, on the other hand, can frequently take decades and often does not have a central city focus. For the most part the focus is on the metropolitan area or region.

Institutional Fragmentation

Institutional fragmentation characterizes both transportation and economic development bureaucracies and impedes greater collaboration between the two fields.

The responsibility for transportation is divided among a myriad of actors at every level of government. Federal, State, and local agencies all participate to varying degrees in the planning, funding, and implementation of transportation services and policies. This geographic and functional division makes coordinated transportation planning very difficult.

In addition, State and Federal transportation programs are divided according to mode. This modal orientation has fostered a competitive rather than a collaborative attitude among transportation planners.

Economic development, which incorporates aspects of several different fields, is especially hampered by institutional fragmentation. At the Federal level, the Economic Development Administration (EDA), the Department of

Housing and Urban Development (HUD), the Community Services Administration (CSA), and the Small Business Administration (SBA) all address economic development issues. Other departments, such as the Department of Labor (DOL), are beginning to examine economic development concerns.

Responsibility for economic development is also fragmented at the local level where numerous public agencies each address a different aspect of economic development, such as job training, community development, and industrial retention. Civic, neighborhood, and local business organizations also have a voice in economic development policymaking. Because these local entities, both public and private, have evolved largely in response to Federal program areas, institutional fragmentation at the local level reflects the division at the Federal level.

Absence of Comprehensive Planning

The lack of comprehensive planning within each field and the difficulty in coordinating the schedules of economic development and transportation programs and projects are additional constraints to integrating the two disciplines.

There is a tendency for local economic developers and transportation planners to concentrate on securing Federal grants for development projects, rather than on long range planning. This project orientation is reinforced by three factors:

1. Local policymakers and elected officials gain political popularity by obtaining Federal funds for the community.
2. Local economic development practitioners try to develop a track record and credibility on the basis of highly visible, successful projects.
3. Federal funds are often only available for these activities.

Furthermore, when local transportation and economic development agencies do collaborate, it is frequently on a specific project or an ad hoc basis, and not part of an ongoing, joint planning process.

Additionally, most cities have not undertaken comprehensive economic development planning. Through its 302(a) planning grants, the Economic Development Administration has encouraged more than 100 cities to do strategic economic development planning. However, comprehensive economic development is still in its infancy, and most cities do not have the staff and resources to undertake it, nor does a methodology or theoretical framework exist that provides them direction.

Lack of Consensus on the Role of Transportation

The integration of economic development and transportation cannot occur until transportation planners agree on the role of transportation. What can or should transportation do for urban economic development? What should Federal transportation programs try to accomplish? How should transportation dollars be spent and for what ends--greater mobility, downtown revitalization, access to suburban jobs, lower energy consumption? Is urban economic development a legitimate goal?

Transportation policymakers hold widely divergent views on what the role of transportation should be. Few people regard urban economic development as part of the U.S. Department of Transportation's mandate. In fact, frequently, transportation legislation precludes the use of transportation monies for purposes other than transportation. These attitudes, combined with limited research and "how-to" information, restrict the economic development potential of transportation investments.

Recommendations for Future Research

In light of the limited state of the art, there are many opportunities for additional research. A conceptual framework or overview of how and to what degree transportation can complement urban economic revitalization efforts has yet to be developed. Few studies have examined comprehensively the use of transportation as an economic development tool. A review of the transportation/urban economic development literature ("Synthesis of Literature on Transportation/Urban Economic Development," CUED, 1980) found that most research examining the relationship between the two fields had been undertaken to solve a specific problem, forecast or assess impacts, or evaluate particular programs or projects. Consequently, it is usually site-specific or pertinent to only a limited geographic area. Although these studies illustrate one city's experience, the local planner or policymaker in another city needs to read "between the lines" of several such documents to glean any useful information of wider applicability. For instance, local officials who are contemplating building a rapid rail system cannot determine from the current literature whether a new rail system will have the same impacts on their city as it had elsewhere, or how to achieve maximum impacts.

Furthermore, the methodology for predicting the economic development impacts of transportation investment is not adequate, nor can the development impacts of existing transportation facilities be easily determined. For instance, most transit development impact studies have not been able to determine the extent to which rail improvements affected land use changes. Was the transit system the major cause or just one of many determinants of new urban development and private investment?

The local policymaker interested in using transportation for urban economic development has few resources to guide his decisionmaking process. The local practitioner needs research that provides guidelines for facilitating desired economic development. Most of the existing literature assumes that the desired economic development will automatically occur as a result of the transportation improvement.

Guidebooks, therefore, are needed to outline how the two fields can be linked. Ideally, this research would take the form of a comprehensive catalogue that examines all of the possible linkages between transportation and urban economic development. It would outline:

- how joint transportation/economic development planning can be undertaken,
- what techniques can be used to achieve these various linkages,
- the pros and cons and the costs and benefits of each technique, and
- Federal and local capability of implementing these linkages.

Case studies should be the foundation of the catalogue, which would show Federal and local officials how to select and implement transportation/urban economic development programs and projects.

Unfortunately, the transportation/economic development literature is still too limited to make such a catalogue possible and the economic analysis and public investment decision techniques available to policymakers are largely inadequate. Yet, if transportation policy decisions are to be made with complete knowledge of their impacts on urban economies, and if transportation investments are to be used to advance economic development goals, better analytical tools are needed.

In the decade ahead, economic developers and transportation planners will need to jointly address new problems and emerging policy issues such as:

- How can cities cope with possible service stoppages caused by the deregulation of the airline, railroad, and trucking industries and capitalize on new entrepreneurial opportunities posed by service changes?
- What transportation investments will best complement the shift in urban economies from manufacturing to services with growing reliance on high technology businesses?
- How can the private sector be encouraged to assume greater responsibility for transportation and economic development?

With the likelihood of greatly reduced Federal assistance for urban economic development and major transportation investments, it will be even more critical for local economic development and transportation specialists to pool their resources for maximum utility.

NOTES

1. This paper is based on research undertaken for the U.S. Department of Transportation.

2. Joint development refers to a real estate development that is either physically or functionally connected to a transportation facility.

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FINANCIAL PROFITABILITY AS AN INVESTMENT CRITERION FOR TRANSPORT PROJECTS

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Abstract

The paper takes as its starting point the need for clear, comprehensive, and objective investment criteria for the assessment of transport projects. It describes the main differences between cost-benefit analysis (CBA), as used in the public sector, and price-earnings analysis (PEA), as used in the private sector, and explores the possibilities and limitations of using the tools of financial profitability as investment criteria in the public sector.

Financial profitability criteria are already used in the public sector, for example in the electricity and telephone services. In the public transport sector they are used for railway, shipping and other revenue-earning services, albeit imperfectly. The paper reviews the pricing principles used in the private sector and considers how they can be applied to charging for the use of transport infrastructure, particularly roads. It is concluded that the pricing tools already available, fuel taxes and annual license fees, could be made to reflect the main costs arising from the provision and use of roads. Given a system of prices that broadly reflects the relevant costs, investments in transport could follow, in general, the investment rules of the market economy.

Some of the difficulties with the proposed system are listed and discussed. It is proposed that more work be done to identify transport costs and to make charges more responsive to them.

Introduction: Transport Planning is in Trouble

Despite a massive infusion of economists, planners, sociologists, "environmentalists" and others into the transport planning process, the last twenty years have seen an abundance of planning disasters coupled with the absence of a consensus on what went wrong.[2] BART, Concorde, Maplin and London's "Motorway Box" are but a small selection of soured projects. On a more general level, neither the U.S. Department of Transportation nor the British Ministry of

Transport appear to use any systematic methodology for comparing investments in different transport modes with one another. It is possible that the lack of a clear and objective investment methodology is a root cause of this unhappy state of affairs.

The Need for a Transport Investment Criterion

Transport planning involves the setting of investment priorities. The setting of priorities requires appropriate investment criteria or measuring rods. Comprehensive (multi-modal) transport planning requires such investment criteria to cover all modes, and public sector investments financed by tax revenues need to be compared with the private investments they displace. Where can we find appropriate investment criteria? Can the previous speakers help us? William Tye concludes that "economically vital investment projects can no longer take a back seat to economically dubious projects." All of us will agree with this, but how is "economically vital" to be distinguished from "economically dubious?" Ulrich Ernst said that "Our understanding of the interactions between transportation policies and economic development is too sketchy to allow for deriving any firm performance criteria for transportation from economic policy goals." If, however, we have no "firm" performance criteria, we cannot prevent any project, however dubious, from being brushed up and implemented at taxpayers' expense.

This brings me to the fundamental point that performance criteria should be related not only to what is theoretically desirable, but also to the reality of the funding processes that govern public sector transport investments. Public agencies in transportation, in all countries, face immense pressures to spend, and these pressures may relate more to the interests of the providers of the proposed projects than to the interests of the users. Furthermore, projects in preparation acquire their own momentum and, once proposed, are difficult to stop. As was said at the opening meeting by Charles Baker: "Social scientists, to a large extent, and government policymakers, almost without exception, have great difficulty accepting negative findings. This is hardly surprising, for as people work hard developing notions, and policies, and strategies, the idea of failure and thus withdrawal or redirection comes hard. In short, true performance measurement is a discipline that few in society truly enjoy and transportationists are no exception."

The importance of inter-modal comparisons may be illustrated by the following figures comparing some of the characteristics of inter-city rail and bus services in the U.S. in 1976:[3]

Inter-City Public Transport - 1976

	Rail	Bus
Places Served	500	15,000
Passengers Carried	18M	340M
Proportion of Passengers from Households Earning Less Than $10,000	38%	60%
Cost per Pass-Km	9¢	3¢

Inter-City Public Transport - 1976 (Continued)

	Rail	Bus
Fuel Consumption, Pass-Km per Liter	11.6	30.6
Cost for 364 Km Trip	$44	$17
Payment by Traveller	$16	$17
Government Subsidy	$28	-0-

The massive support given to an outdated and less efficient operation might be considered a waste of public funds, but this is not its only drawback. What might be even more important is that the subsidy to rail undermines the competitive mode, the inter-city bus, which can still operate without subsidy.

Cost-Benefit (Economic) Analysis vs. Price Earnings (Financial) Analysis

One of the main difficulties in formulating an investment rule that would apply to all transport projects is that some modes, such as railways, buses and air carriers, provide services that are paid for by users, and the investments in these modes can be justified by the profits that they generate to the producers, without regard to the benefits enjoyed by the consumers. In the private sector, investments are typically justified in this way, which might be labeled a "Price-Earnings Analysis" (PEA). On the other hand, facilities such as roads and waterways are popularly regarded as "free," with no charges levied for use. They are, therefore, generally assessed not by their profitability to their suppliers, but on the basis of "Cost-Benefit Analysis" (CBA) which ranks alternative schemes by comparing the benefits to society from each scheme with its costs to society. Thus, PEA differs from CBA in two major respects.

First, PEA excludes, and CBA attempts to include, benefits other than the financial return to the investor. It follows from this that, other things being equal, a project offering a certain price-earnings ratio is preferable to one offering the same cost-benefit ratio, because the former excludes and the latter includes benefits to others. For example, a railway investment offering 10% a year to the railway company is likely to be preferable to a highway investment offering the general public a return of 10% a year, as the 10% accruing to the railway company has to be added to the benefits accruing to the users, which do not appear in the calculations of the investor. Similarly, a government that takes money from a private investor and uses it to fund a project giving a 10% economic return may not be doing its economy much good if, by this investment, it deprives the private investor of making an investment that brings a 10% return to him or her. It was once thought that investments by public agencies were, per se, more beneficial than investments by the private sector, but it is becoming increasingly difficult to find officials who still believe this. Moreover, it should not be assumed that the benefits from revenue-producing projects go only to the suppliers. Freddie Laker's transatlantic air services produce substantial benefits to the consumers, in addition to the enrichment of Sir Fred.

The second fundamental difference between PEA and CBA is that the former is carried out on the basis of market values of inputs and outputs, while the latter attempts to measure "economic" values, by means of "shadow pricing." For example, a financial analysis would generally value imports by the amount paid for them by the investor. If, however, these factors are over-valued because of tariffs, or under-valued because of fictitious exchange rates, the cost-benefit analysis attempts to correct for these differences.

To the extent that public investment is at the expense of private investment, it is clearly desirable that both be measured by the same measuring rod, namely profitability to the supplier--nobody has yet suggested that private investors should act in accordance with cost-benefit analysis calculations. To the extent that market prices diverge from economic prices, even investment based on profitability will be non-optimal. For example, the actions of previous United States Governments in holding gasoline prices at below market levels resulted in an excessive production and use of automobiles with a high gasoline consumption. The authorities attempted to deal with the situation by passing a series of regulations designed to force the manufacturers to produce "energy saving" vehicles. Experience of this and other situations suggests that it may be better for governments to allow market prices to reflect economic scarcities than to induce distortions and then attempt to correct their effects by other interventions in the workings of economic markets.

Much of the effort that has gone into multi-modal transportation planning has been directed at developing CBA to enable it to deal with revenue-producing, private sector projects, such as railways, within the framework developed for the assessment of non-revenue-producing projects such as roads. The method required that total benefits to consumers, producers, and even the general public be worked out for each project component and compared with the appropriate costs. The difficulty and ambiguity of such calculations enable poor projects to be "justified" on the basis of alleged "social" benefits. For example, according to U.S. Senator Domenici (New Mexico), the inability to measure the social demand for navigation projects leads to a "slipshod analysis of whether new projects are needed or not."[4]

The Use of Financial Profitability Criteria in the Public Sector

The criteria of financial profitability are already widely used in the public sector, for example, in electricity, in telephone services and (in the transport sector) in railway, marine and aviation services. It cannot be claimed that the investment criteria used in these public services give no cause for concern. To the extent that cross-subsidies force some services to be paid by the users of others, the system works imperfectly. For example, users of peak hour services in public transport and electricity are frequently subsidized by non-peak users. (It may be noted, in passing, that this sort of cross-subsidization can only be carried out successfully by an agency not subject to competition.) But, by and large, the fact that an agency has to show a profit at the end of the year gives its staff clear signals as to which services to contract and which to expand, and gives the government an indication of which managers to promote and which to retire.

It would seem then, that there may be something to be said for using the measuring rod of financial profitability as an investment criterion in the transport sector. In fact, the main transport sub-sector in which profitability is not used as an investment criterion is roads, and it may be no accident that it is in this area that the most severe transport problems appear which manifest themselves in the form of traffic congestion in cities and under-utilized highways outside them. The rest of the paper will be devoted to a sketch of how profitability might be used as an investment criterion in the roads sector, and in dealing with some of the difficulties that such a policy could involve.

Pricing Principles

As has been mentioned earlier, the financial criterion of profitability is already used in many parts of the public sector, including electricity, telephone, railway services, airport landing fees, etc. The common denominator in all these services is that they are revenue earning. It is the fact that users pay for the service that enables the providers to profit, and hence to judge investments on the basis of profitability. Where payment is not possible, as for example in the case of the provision of water in some low-income cities, the criterion breaks down. Therefore, the first question that has to be faced is whether it is possible to set up a charging system for road use based on the objectives and principles of efficient resource allocation and market pricing. In the transport sector these principles require that every user meets his (or her) share of the costs resulting from use, no more, and no less. Only in this way can one ensure that the extra cost entailed in the "production" of a bit more travel is balanced by the extra satisfaction obtained from it. Two separate elements comprise the costs associated with the use of transport facilities:

1. Direct Costs: Costs imposed as a result of resources directly consumed in making the transport facility available: wages, fuel, wear and tear, atmospheric pollution, etc.

2. Congestion Costs: Costs imposed by users on one another when the demand for a service exceeds the available supply. (This applies only when direct costs are charged.) These costs arise out of scarcity which, in principle, enables additional charges to be levied for the use of the scarce facility. In this sense, it may be said that congestion costs arise because of under-pricing, or, in economic jargon, because sufficient "rents" are not charged for the use of scarce resources.

While the importance of direct costs is generally recognized, congestion or "rent" costs are often ignored. Their significance can be illustrated by the imbalance between the two federally operated airports in the Washington, D.C. area, Dulles and National. While Dulles Airport, which is further from the center than National, has plenty of spare capacity, the demand for landing "slots" at National Airport at current landing charges exceeds the supply, and the U.S. Department of Transportation has to go through a process of rationing the available spaces, offering slots to some airlines and denying them to others. If the significance of congestion costs were recognized, the landing rights at National Airport would be auctioned by a process of bidding. The resulting higher landing charges at National would shift some traffic to Dulles and, incidentally, the additional "rents" for landing rights would increase the public revenues.

Charging for Road Use

The main methods currently available for road use charging are fuel taxes and annual license fees. The fuel tax increases with vehicle weight and with distance travelled, and can be used reasonably to levy a payment for direct costs in the same way that the unit electricity charge is imposed to reflect the cost of providing additional units of electricity. Its main disadvantages are (a) it is generally too low to reflect the costs imposed under conditions of severe congestion, and (b) if applied equally to all fuels, it undercharges vehicles using diesel fuel, in comparison with those using gasoline. The latter difficulty can be overcome by taxing diesel fuel used for road travel at a higher rate than gasoline. (In many countries the situation is perverse, with diesel fuel being taxed at a lower rate than gasoline.)

The annual license fee can be used to levy additional charges for vehicles that impose particularly high costs on the road network, for example, commercial vehicles with heavy axle loads. In the absence of a congestion charge, it can also be used to meet capital and other costs that do not vary with road use. This would correspond to the periodic "standing charges" levied for the use of telephone, electricity and water services. Thus, it would appear that a combination of fuel taxes and annual license fees set at appropriate levels could be made to reflect the main costs arising from the provision and use of the majority of roads. The correspondence between costs and charges would probably be no worse than that taken for granted by the providers of other public sector services.

To give an example and illustrate the magnitude of the figures involved, one can consider road travel in the United States in 1976. Figures provided by the Federal Highway Administration (Table 1) indicate that the amounts spent on the road network (rural and urban) averaged 0.6 cents per vehicle-km (0.9 cents per vehicle-mile) on operating the system and 0.7 cents per vehicle-km (1.2 cents per vehicle-mile) on constructing and expanding it. Assuming an average fuel consumption of 6.38 km per liter (15 miles per gallon), a tax of 4 cents a liter (15 cents per gallon)--equivalent to 0.6 cents a vehicle-km or 1 cent a vehicle-mile--would have covered the total costs of administering and operating the existing highway system. If all the $17,049 billion of 1976 capital expenditure were charged to the nation's 1976 population of 28,197,900 commercial vehicles, the annual tax on each truck and bus would have averaged $605; if the capital expenditure were charged entirely as an annual tax payable by the nation's total 1976 population of 143,538,500 vehicles, the average annual tax per vehicle would have been $119.

Table 1. Disbursements for U.S. Highways in 1976 $ Billions

	Federal	State	Total Federal & State	Counties and Town-Ships	Munici-palities	Total Counties Townships, Municipalities	Grand Total
Capital outlays	0.375	10.580	10.955	1.470	1.870	3.340	14.295
Interest on debt	–	0.896	0.896	0.093	0.235	0.328	1.224
Debt retirement	–	0.920	0.920	0.170	0.440	0.610	1.530
Subtotal Capital	0.375	12.396	12.771	1.773	2.545	4.278	17.049
Maintenance	0.098	3.165	3.263	2.520	2.100	4.620	7.883
Administration	0.260	1.237	1.497	0.350	0.370	0.720	2.217
Law enforcement	–	1.424	1.424	0.205	1.000	1.205	2.629
Subtotal Operating	0.358	5.826	6.184	3.075	3.470	6.545	12.729
TOTAL	0.733	18.222	18.955	4.808	6.015	10.823	29.778

Vehicle-km (billions)	Capital	1,015.23	1,252.58	2,267.81
Expenditure/v-km	Capital	1.26	0.34	0.75
	Operating	0.61	0.52	0.56
	Total/v-km	1.87	0.86	1.31
Vehicle-miles (billions)		630.84	778.32	1,409.16
Expenditure/v-mile	Capital	US¢2.02	0.55	1.21
	Operating	0.98	0.84	0.90
	Total/v-mile	3.00	1.39	2.11

Source: Federal Highway Administration, Selected Highway Statistics, 1976. Washington, D.C. 1973

The purpose of this example is not to recommend any particular combination of taxes, but to indicate that there appears to be no insuperable difficulty in devising a tax structure that would enable the totality of road users to be charged the total cost of United States roads. However, two problems remain:

1. Any charging system that relies on taxes on fuel and vehicle parts, supplemented by annual licensing fees, would involve a considerable degree of averaging, and would not meet the requirement that each significant element of a transport system meet the test of profitability, and

2. The use of such taxes would tell us nothing about the optimal size of road networks, nor whether they should be expanded or contracted, as the "profits" from any road system could be arbitrarily increased by raising the taxes.

Regarding "averaging," tools can be used and are being used to charge for many roads (particularly for costly sections such as bridges), and the toll road industry is in fact developing new pricing methods to enable charges to be assessed against moving vehicles. However, a considerable amount of averaging has to be accepted as a fact of life. The diseconomies of averaging are particularly evident in the absence of charges for the use of congested urban streets (see Congested Roads below), but the absence of "road pricing" need not prevent improvements in the financing of other elements of the transport system. Tax rates on road use in the United States already vary from state to state.

Regarding the optimal size of road networks, extremes of under-investment can be avoided by allowing private suppliers to build new road sections and to be reimbursed from the fuel and other taxes "earned" on their roads. The appropriate amounts could be determined by traffic counts and could replace, or supplement, tolls. Over-investment would be more difficult to deal with, particularly if associated with high taxes and poor planning, but an efficient administration, supported by a vigilant and educated electorate, would tend to exert its influence to cut taxes and improve planning.

The Investment Rule

Given a system of prices that broadly reflects the relevant costs, road investment could, in general, follow the investment rules of the market economy: investments that increase profitability would be undertaken up to the point at which "normal" profits are earned, while investments that do not bring profits would be avoided. This approach would have, as a bonus, a rational criterion for comparing investments in different revenue-earning public sector enterprises: the return on capital invested. (Even the most avid supporters of cost-benefit analysis do not claim that it can be used to compare investments in different sectors, for example, water versus electricity or telephones ver us airports.) A profitability criterion would also enable comparisons to be made between investments in private and public sector enterprises.

Objections and Difficulties

There would undoubtedly be difficulties with the system proposed due to:

- situations where suppliers enjoy monopoly conditions,
- the existence of substantial "external" effects,
- the treatment of congested roads,
- the provision of roads for sparsely developed regions,
- the transport "needs" of poor people, and
- the "need" of governments to collect revenues.

A few words can be said about each of these points.

Monopoly Suppliers

As a monopolist is in a position to raise prices to whatever level is necessary to reach profitability, the criterion of profitability may not be appropriate where a public agency enjoys a monopoly. The direct way of overcoming this difficulty is to break the monopoly and allow competition. Generally, this is feasible in such fields as public transport, electricity generation, long-distance telephone services, and waste collection, but technically difficult in some cases, particularly those involving a distribution network which is costly to duplicate. In such circumstances the supplying authority should be required by law to charge the prices that would be determined by a competitive market, that is, prices that "clear the market" and equate supply and demand. The profits and losses made under such "market clearing" prices would, in general, signal the need for investment or disinvestment. Even if, for technical reasons, it is felt necessary to grant local monopolies, it does not follow that all have to come under one umbrella organization. For example, in the United States each area has a separate and financially independent electricity and water authority, all of which are governed by similar principles but fix their prices and investment programs independently. The existence of separate suppliers side by side gives consumers some protection in that comparisons can be made between different areas, and lessons learned in one can be applied to another.

"External" Effects

By definition, "external" effects affect others either as benefits or as costs, and these effects do not enter into the accounts of the activity that causes them. While cost-benefit analysis, also by definition, can explicitly take account of such effects (where they can be quantified), it does not follow that only cost-benefit analysis can do so. If the magnitude of the effects are known, they can be "internalized" by requiring payments from the factor causing the external effect. For example, operators of noisy aircraft can be charged a "noise fee" which would influence their profitability and their choice of aircraft. Similarly, "positive externalities" can be recognized by payments to the factors bringing them about.

Congested Roads

Traffic congestion, particularly in urban areas, is frequently associated with under-pricing, which results in vehicles imposing on one another costs far in excess of the amounts paid for the use of congested roads. A situation of this kind could not arise under a perfect market system because the owner of a congested road would charge a rent for its use, which would reduce congestion to a level that maximized its output and his profit.[5] The rational way to deal with this sort of situation is to impose a special charge on the use of congested roads, as has been discussed frequently in recent years.[6] In 1975 such a system of charging was introduced in Singapore where vehicles carrying fewer than four people are required to pay a special fee to enter the central area in the morning peak period. The scheme has proved to be enforceable and effective in reducing congestion. In the United States, the International Bridge, Tunnel and Turnpike Association is developing new methods of payment for the use of toll roads and bridges to supplement (or replace) the time honored method of throwing coins into baskets. These methods, which could also be used to charge for the use of congested roads, involve affixing on each vehicle an "electronic number plate" that would be uniquely identified by its response to electronic interrogation and thus enable vehicle owners to be billed for road use.[7] The absence of congestion charges does not, however, destroy the case for the use of profitability as a criterion for road investment; the lack of pricing signals to determine appropriate levels of traffic on congested roads raises similar difficulties with cost-benefit analysis.

Roads in Sparsely Developed Regions

The profitability criterion may not be usable for lightly loaded rural roads. This is due to the technical factors underlying road construction. A road has to be wide and strong enough to carry vehicles. Under conditions of light traffic such a road may be used only to a fraction of its capacity, but it is not possible to accommodate the traffic by building a narrow path that would be used to full capacity. The choice is either a minimum sized road or no road at all. The option of providing half a road does not exist. In theory, cost-benefit analysis can solve this problem by assessing the likely increased production that would result from the provision of a road in a sparsely populated or developed area. In practice, however, it is doubtful whether such calculations can be used, as few countries have sufficient planners to enable the necessary calculations to be made even for their major roads. One way of dealing with the situation might be to establish a system of matching grants, with a county or state government matching contributions made by local farmers or villagers, either in cash or in kind.

Meeting the Travel Needs of Poor People

It is sometimes suggested that the requirements of poor people preclude the possibility of using profitability as a criterion for investment in roads or in any other form of transport. This is by no means self evident. Food can be produced for profit, with food stamps being used to help the needy. In the transport sector it is also possible to deal with the needs of special groups by direct assistance, for example, regional development grants or travel vouchers.

The Need of Government to Collect Revenues

It is sometimes suggested that governments need revenues, and that it makes no more sense to devote the proceeds of road taxation to road building than (for example) to devote the proceeds of alcohol taxation to rest homes for alcoholics. But this is to confuse two separate elements: payment for services rendered and payment of taxes. It is always open to any government to tax the use of roads or the profits of highway authorities, as indeed the profits of public utilities are often taxed. Nevertheless, it is important to make a clear distinction between monies paid for the provision of goods and services, and tax payments to city, state or federal authorities. Many countries levy taxes on the use of electricity and telephone services, but they do not do so by requiring all electricity and telephone revenues to be paid into central revenues. There is no inconsistency between government's need to raise revenues and its need to have its investment programs assessed by clear investment criteria.

Conclusion

It may be concluded that, given charging systems that relate prices even roughly to costs, investment criteria based on profitability (PEA) can offer decisionmakers objective measuring rods for comparing different revenue-earning projects with one another and with private sector investments. The main difficulties to be overcome are:

- The need to collect appropriate cost data, particularly in the highway and waterway sectors;
- The need to persuade treasury officials that the introduction of such a system would strengthen, not weaken, the public revenue; and
- The need to develop improved pricing systems, specially for the use of congested roads.

Postscript

In opening this symposium, the U.S. Secretary of Transportation said that he saw his job as "not to prop up inefficient systems through endless subsidies, but to focus federal funds on those high-payoff areas where wise capital investments will result in better performance." Will he be able to so order things in his department that market prices, and investment criteria based on financial profitability, could be used to identify those high-payoff areas where wise capital investments will result in better performance?

Acknowledgement

Thanks are due to Anthony Churchill for perceptive comments and to Maritza Simpson for preparation and typing.

NOTES

1. The World Bank does not necessarily endorse the assumptions, data or conclusions presented in this paper.

2. Peter Hall, "Great Planning Disasters," Weidenfeld and Nicolson, London, 1980.

3. N. Bade: "Inter-city Bus Transportation: A Changing Market." Paper presented to the 57th Annual Meeting of the Transportation Research Board, 1978.

4. Congressional Record, 24 February 1977, p. S2965.

5. Frank Knight, "Some Fallacies in the Interpretation of Social Cost," Quarterly Journal of Economics 38 (August 1924):582-606.

6. Ward Elliott, "The Los Angeles Affliction: Suggestions for a Cure," The Public Interest 38 (Winter 1975).

7. Robert S. Foote, "Prospects for Non-Stop Toll Collection Using Automatic Vehicle Identification," paper presented at the International Bridges, Tunnel and Turnpike Association Annual Meeting, Tarpon Springs, Florida, December 1980. (Obtainable from the author at the Port Authority of New York and New Jersey.)

STATE OF THE ART ASSESSMENT OF MODELS RELATING TRANSPORTATION SYSTEM OPTIONS TO ECONOMIC DEVELOPMENT CONSEQUENCES

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Abstract

The purpose of this paper is to assess the current capacity and state of the art of economic analysis and analytic model building to assist policymakers in relating transportation system choices to economic development consequences and requirements. Results of this assessment are in terms of decisionmaking benefits and costs flowing from both likely and more problematic methodological and data base improvements. The difficulties of meeting decisionmakers' needs are spelled out and ways of meeting these needs identified.

The spectrum of techniques and performance indicators investigated include: micro and macro; transportation demand and supply; partial and general equilibrium modeling; direct, indirect, and induced effects; effectiveness and efficiency measures; and descriptive as well as normative techniques. Both traditional (e.g., GNP, national income and employment) as well as non-traditional (e.g., national security, international competitiveness, distributional, and wealth effects) economic development performance indicators are examined, in relation to a wide range of transportation systems variables. A specific transport system change is used as an illustration of ways to combine the use of several analytic approaches in a decisionmaking context. Alternative strategies for improving the state of the art, where policy and decisional benefits warrant, are also discussed.

Introduction: Decisionmaking Needs

Students of transport economics are quick to point out that "transportation is not an end in itself" but rather exists to serve the needs of the economy, and hence, the society. With increasingly difficult choices involving scarce transportation system investment and operating resources, one could reasonably expect that when these hard decisions--whether public, private, or mixed--are made, external factors, including prospective economic development impacts of service changes, will be among the determining factors as to which alternative society will seek to adopt.

Positive or negative development effects in one region, or one part of a region, frequently cause substantial economic changes in other parts. Transportation information systems, I believe, need to acquire, retain, and disseminate such economic impact data. It is the central premise of this paper that properly conceived measures of "output" could and should assist in developing new information sources which, in connection with existing ones, will facilitate national, regional, and local decisionmaking processes concerning transportation matters and economic development. Broad, routinized measures of the place of the transport industry or its various sectors and subsectors in the development of the national economy and its regions would be illuminating in many ways that we cannot--nor, in my opinion, need to--tie down to any particular level of decisionmaking responsibilities.

A priori, can we say anything further about some of the characteristics of measures reflecting how transport impacts the national and regional economies that might be most useful? A point or two, before going on. Public policy does not manage the nation's transportation systems with a commissar's power over it. Its responsibilities and powers are broad, it is true, but:

- decisions are made on top of rather than in place of millions of business and consumer decisions to sell and buy transportation services;
- public policy is more of a strategic intervenor than a comprehensive entrepreneur in the transport industry;
- public policy is concerned with increments and decrements in transport output and input rather than in wholesale changes.

Why Is It Difficult to Meet the Decisionmaker's Needs: What Can Be Done About These Difficulties? 1

We should like to have a set of measures reflecting, minimally, the "bedrock" needs, or those which aggregate the economic development activity resulting from transportation-related decisions in ways which meet certain objectives:

1. Reflects the overall utility of transportation of the economy
2. Reflects the general health of the industry
3. Advises on public interventions

Measures of gross (national and subnational) economic activity are ordinarily taken to fulfill objective (1) for all goods and services in the economy: the value of goods and services produced and consumed by all sectors for all sectors, in all regions and each region (i.e., gross national product, and national income measures), is taken to be a reasonably good measure of the overall utility of these goods and services to the American people. These are often taken to reflect the state of health of the economy also and its individual sectors (industries), i.e., objective (2).

"Transportation" measures, by and large, suffer by comparison with measures of total economic activity in several ways, in terms of meeting the requirements for measures of objectives (1), (2), and (3). Since transportation is only one significant part of the total economic system, measurement of transportation's contribution to the national income generally, and national and subnational economic development more specifically, is perhaps much more complex than the measurement of national income and product itself. Some of the reasons for the difficulty of relating transport services to resultant economic development are noted in Exhibit 1. These may seem to be rather technical reasons for the difficulties observed. "Technical" or not, the problem has long been recognized.[2]

Unfortunately, in many respects, the problem is not significantly closer to a satisfactory solution. In the latest reviews on the subject,[3] there is a fair degree of agnosticism expressed in terms of what we already know about the relationships of transportation systems and their impact on economic development. Nevertheless, some progress--to which I shall now turn--has been made. The next sections discuss what we would like to know in this regard and where--more or less--we stand today in our abilities to know.

Some Things We Would Like to Know

Transportation investments in rural as well as urban regions of a mature developed nation play a many-faceted role in the pursuit of development and distributional objectives. A direct impact of transportation system investments, it is true, is their income generation role through their stimulation of demand for goods and services.[4] These projects also have effects on human capital, improving its productivity and thus, augmenting the regional production of goods in the long run. By reducing factor costs, these projects generate internal economies for many sectors, thereby fostering external economies for all sectors. Further, such investments in certain regions, by generating growth in new sectors, may result in larger "agglomeration" functions and upgrading of the centers of the urban hierarchy and consequent urbanization economies that spur further growth and development.

Thus, there is little doubt that transportation system investments generate a wide range of benefits, other effects, and incur attendant costs. An identification and measurement of these consequences and costs, most transportation systems analysts and economists agree, must be done through an overall comprehension of the economic panorama in the affected rural and urban areas, among regions, and the nation. Such an analytical framework, following earlier works of Edgar Hoover, the famed regional economist, would investigate the impacts of public investments from:

- the locational viewpoint: the role of transportation investments in improving the comparative advantage of specific industries, population groups, and factors of production;

- the regional viewpoint: the interrelations among transportation system projects in terms of their developmental impacts within a region over time; and

- the interregional viewpoint: the economic interrelationships among sectors, between regions, over time, resulting from transportation projects both, within and between regions.

Closely related to these geographical or spatial impacts are the incidental results of transportation systems: who benefits, loses, and/or is otherwise affected by the economic development consequences? True a decade ago and still a major weakness of the vast majority of transportation system studies, is the scant attention to the matter of the distribution and redistribution of benefits and costs. Transportation projects are often targeted, directly, for a number of "client groups" but may very well impact on a variety of other client groups in an indirect, unintended manner.

Several issues are important here. The characteristics of the local communities where the transportation options are "located" influence to a great degree the incidence of the benefits. For example, the employment status, occupational or industrial affiliation of the persons in the community where a transportation investment is made may be highly relevant to who captures the immediate benefits, or suffers losses, occurring from a transportation investment project.

The delineation of these types of incidence-spatial effects is no easy matter, and certain aspects of incidence, for instance the temporal aspects, are even more difficult to discover. Complex frameworks, those discussed in the next section, are needed to further analytical progress across these dimensions.[5]

Analytical Approaches: Theory and Application

This section begins with a discussion of key aspects of the economic theory of spatial (e.g., regional) interrelationships which are important in estimating the types of economic development impacts under consideration here.[6] Externalities, not directly reflected in a firm's costs, are also considered. Finally, a discussion of the requirements for analytical tools is offered to serve as a basis for the consideration of the status of available tools.

Economic Theory

Economic theory asserts that the ability for one area and/or region's firms to compete in markets outside the area/region is critical to the economic health of that area/region. Economic base theory[7] states that a region's export industries are its economic foundation and its source of growth. Other industries are theorized to exist for the purpose of "servicing" these basic export industries, as well as one another. Changes in the output levels of the export industries lead to changes in the output level of the local (non-export) industries. Thus, factors that increase a region's ability to export have a magnified impact on the local economy and vice versa: this is standard Keynesian multiplier theory. How transportation factors influence the economic base is the crux of the connection to economic development.

In order to understand what factors might affect an area's ability to export, we must consider why a firm can export products at a considerable distance from its plant. We take it as axiomatic that a firm can compete in a particular market if it can supply a particular product to that market at a delivered price less than or equal to the price at which any other firm can supply the particular product. Thus, the number of markets--regions of the country, and in other countries--in which a firm can compete is dependent on the firm's delivered price in each market.

How an Economy is Interrelated: General Equilibrium

A national economy may be viewed as consisting of many interdependent economic subsystems. Each of these subsystems, or regions, will produce goods and services for itself and export to some or all of the other regions.

In a state of equilibrium, a pattern of shipments between the regions will exist. As the previous section states, this pattern will be based on producer's prices within a region and transportation costs between regions. Because of material and production costs, some goods will be made in a few regions and exported to all other regions. Other goods will be produced in all regions and little or no export trade will exist.

Over time, various forces will change producer's prices and transportation costs, changing the interregional flows, and the economic base of each region. Some regions will grow and some will decline. These aspects of dynamic general equilibrium are key to a study of economic development impacts. The effects that change in producer's costs and transportation costs has on the economic well-being of a region are at the core of such consequences.

The next section describes how changes in transportation costs affect a region, not only directly, but also indirectly through changes in production costs.

Direct and Indirect Effects of Transport System Changes: An Illustration

An illustration involving the economic impact of reduction in rail service is useful at this juncture.[8] Such reductions, be they a disinvestment or a change in rail operations, can be directly translatable into increased transportation costs for some firms. These increased costs will mean that a firm's product may no longer be competitive in some markets, and sales will decline, while some other firm(s), in some other regions, will likely increase its sales.[9]

Sales will be affected not only by a firm's inability to compete in some markets, but also by the fact that, at the increased price, some consumers will no longer purchase the firm's product--choosing some alternative good, or doing without. This substitution effect and the loss of markets are normally considered together as price elasticity, whereby the percentage of a firm's output will change relative to a change in price.

However, increased transportation costs can also increase the firm's producer's price. The cost of assembling materials will increase for some firms, also affecting the total delivered price of the product and reducing sales.

In addition to these direct effects, increases in transport costs in a region may have indirect effects not only on firms within the region, but also on firms throughout the economy. These indirect cost increases will come about through increases in the prices of materials used in the production process. For example, increases in the price of transporting coal will affect the price of steel directly and the price of products using steel indirectly.

Thus, in considering the impact of transportation cost changes, we must be aware not only of the direct cost impacts, but also of the indirect cost effects--which may be present not only in the region experiencing the transportation changes, but also in other regions.

We must also be aware of "externalities" as they are known to the economists. Economic externalities may be defined as economic costs of benefits that occur outside the control of the affected parties. (Some economists also consider as "externalities" the firm behavior that is not directly predictable.)

We have already noted (above) that changes in interregional trade patterns will cause some regions to grow and some to decline. In the declining regions, suppliers of declining industries may find themselves producing less output at a higher unit cost, since their market has shrunk. If they pass this increased unit cost on to their customers, they will further decrease their volume and increase the production costs of their customers--leading to further reductions in output. These effects are externalities, since they occur neither directly nor indirectly but because of the level of scale economies present in a particular plant, operating at a specific level of output. Similarly, increased costs in one region could lead to increased demand in another, allowing for scale economies that will reduce costs, and increase output.

Similarly, transportation changes can influence the industrial structure of regions, both directly and indirectly. Some firms, for example, in an imperfectly competitive industry, may have a nearby market in which they have relatively little competition. In such a case, increased transportation costs to faraway markets might be offset by increased prices in the local market--an action the firm, all else equal, would have preferred not to take. A firm might do this to maintain a level of output that realizes significant scale economies. If this were to occur, the firm's output might not be affected to the degree one would expect from increased transportation costs.

Analytic Models and Their Application

"Micro" Methods

The subtleties of the myriad interrelationships between transport changes and economic development are complex and, to the rigorous analyst, often shrouded in mystery. The existence of indirect and/or external effects (as described in the preceding section) make it unlikely that any available analytical method will, by itself, accurately predict long-term, structural, dynamic changes caused by a change in the transportation structure. For this reason, it is frequently important to utilize either case studies or detailed "micro-oriented" field surveys that will give additional information on how regions (are likely to) adapt to changed transportation conditions. There is, in fact, a substantial trend toward such "micro" methods, in the study of economic development consequences, ranging from how new system highway interchanges affect contiguous land development, to the consequences of rail abandonment. While the latter is not to be our primary focus, here, an example is useful, since it helps to illustrate how such "micro" methods are often compatible with the more analytic modeling techniques.

I return to the earlier illustration of railroad system restructuring and abandonment. Over the past seven years, my colleagues have been continuously involved in studies related to termination of railroad service. One of those studies was of particular importance for establishing a benchmark by which to assess impacts on rail users. That is the so-called "CONSAD 1977 Study"[10] which viewed railroad service termination, first and foremost, as a change in the supply of transportation, and determined how shippers and receivers were likely to respond. The results showed that in most cases the traffic would continue to move but by another mode of transportation. Overall, some 40% of the traffic would convert to a rail/truck transshipment form of transportation. Less than 10% of the traffic would cease to move to or from the local area and thus cause net loss in economic activity. Additionally, for that traffic which would continue to move, there would be an increase in transport cost, which would also result in some reduction in activity.

It is important to recognize that the results of the 1977 study did not strictly derive from a theoretical notion as to how the system operates, but, rather, proceeded from detailed and specific studies of actual traffic movements. Given this situation and point-of-view, it was considered crucial to recognize the multitude of factors at work in each such instance, placing strong belief on detailed, case-by-case primary data analyses as the only correct means of precisely determining such responses.

However, "micro" studies can only provide insights into the most immediate of consequences. They cannot, without much "stretching" beyond their original intent, yield insights into sectoral, areal or interareal effects--direct, indirect, and induced. For this purpose, even though economic models may not be able to predict all areal structural adaptations over time due to a restructuring of transportation, they can and do provide reliable estimates of the initial direct and indirect impacts. Such analytical frameworks should be able to consider initial changes in a transportation network--whether from "micro" studies or from less reliable sources--translating these changes into industry-by-industry and community-by-community impacts, then estimating overall sectoral and areal impacts of these changes. The tools, properly selected, should take all of the economic processes discussed above into consideration, allowing for regional changes and cross-regional impacts.

Analytic Methods: General and Partial Equilibrium[11]

It is nearly a quarter of a century since the earliest full-blown transportation impact analysis models have been conceptualized. How advanced are they, currently? Can such models be relied upon to help determine consequences in advance, e.g., of motor carrier regulatory policy regarding entry and exit, rail line abandonments, investment in transportation modes, and other so-called "policy variables"? What alternative methods for "conditionally forecasting" such impacts are there, and how reliable and valid are these methods? Which study methods are best suited for which purpose(s)?

What economics tells us about the study of these impacts--whether it be a matter of the impact of a single abandoned line or one shipper, or an entire multimodal interstate system--is that, in theory, each and every economic variable is affected by all other variables. And, in theory again, when any (one) component is altered, the entire economic system-- i.e., all of its components--will seek a new "equilibrium" level. Estimating what this new level, for all economic variables, will look like is what economists have called "determining a 'general equilibrium' solution" for the entire economic system.[12]

Ideally, policy analysts and/or potentially affected parties to a system change should want to know the impact of each option upon the immediately impacted industrial sectors (e.g., the directly affected modal carriers and shippers) as well as those broader ramifications--for example:

- intra-industry variables, such as output levels, prices or rates, profits, the behavior of short- and long-run cost curves, investment, utilization of the factors of production, productivity, technological change, and others;
- interindustry variables (output levels, prices or rates, etc.), i.e., consequences for industries linked closely to those immediately impacted;
- all industries, even remotely linked, through indirect and induced effects; and
- distributional ("equity") impacts, e.g., income and employment effects for communities and individuals: who gains and who loses?

Ideally and conceptually, estimates of these consequences are what the economist should be able to provide the analyst and/or the interested party.

It is appropriate, now, to look at how operational the concept of general equilibrium analysis, as it has evolved over the years, has become.

Assessing the Operational Status of "General Equilibrium" Economic Models[13]

The first attempt at making operational interindustry and interregional estimates of the consequences of transportation system options was that presented by Leon N. Moses in 1955 and again in 1960.[14] Since the mid-1950s conceptualization of general equilibrium mathematical models, most of the effort in operationalizing these concepts has been concerned with development and acquisition of suitable data bases, improvements in the efficiency of input-output computational methods (both software and hardware), and the design and implementation of appropriate statistical estimation techniques.[15]

It would be overly negative to say that, in these 25 years, significant computational and operational advances have not been made--because, indeed, substantial progress has been made:[16] work by Almon and Harris is frequently used by those making national and regional economic forecasts utilizing interindustry techniques and the U.S. Departments of Transportation and Energy utilize several such models (e.g., Almon, Faucett, Friedlaender, Oak Ridge, and others). DOT/DOE are, in addition, supporting additional research in interregional interindustry modeling.

However, such models are only beginning to deal, operationally, with many of the key economic variables and relationships, the omissions of which can vitiate--or at least substantially lessen their utility--the reliability and forecastworthiness of transportation system impact forecasts developed using such models.[17] Exhibit 2 enumerates a number of these issues.

Quite clearly, the "bottom-line" has to be that general equilibrium models have a long way to go to be of definitive value to potential users. Where the problem is a relatively "simple" one, e.g., determining the impact of a number of abandoned light-density rail lines on shippers and communities, the kinds of transport-sensitive multiregional input-output models described above are clearly "overkill." Economists, by and large, favor partial equilibrium solutions to such problems--solutions in which the central problem can be sufficiently isolated from its general environment so that either simplified models or "expert judgment" can be used to evaluate the output, employment, and income effects, on affected shippers and communities.

On the other hand, when proposed changes in transportation systems are so large that they alter prices other than that of the transportation system itself (therefore feeding back and causing a shift in the demand curve for transportation services), a partial equilibrium approach is no longer adequate.

General Equilibrium in Practice

The general equilibrium approach, to be realistic in practice, is subject to decisions in two areas:

- level of aggregation in industries; and
- level of geographic aggregation.

Ultimately, data availability determines the level of industrial and geographic aggregation, since many desirable series may not be available. In a recent study, sponsored by Conrail, the industrial aggregation is approximately thirty productive sectors and the geographic aggregation is at the state level.

The actual analytical tools employed, to some extent, also influence the level of aggregation chosen; however, it is more accurate to say that the tools employed are determined by the amount of disaggregation available in the data.

With these requirements in mind, we briefly examine the core of the analytical models employed, in practice, to determine the desired impacts:

- Input-Output Models: The generic input-output model is designed to assess the impact of a change in the exogenous value of final demand on the commodity flow and gross output by using the following relation:

Gross Output = Input Requirement + Final Demand

This model properly identifies the relationship between the overall commodity movements by counting the technological constraint associated with the commodity production. The major shortcoming of this model is that the impact of changing transport costs or production techniques cannot be reflected within this equation system. That is, changes in transportation costs can lead to substitution within the final consuming sector (basically government and industry). However, a multiregional input-output system offers a coherent system describing relationships within and among regions.

- Linear Programming Models: Linear programming (LP) models estimate interregional commodity flows relative to minimizing transport costs; however, available LP models provide no breakdown within regions, except through additional assumptions. Furthermore, a serious defect of linear programming transportation models is their inability to accommodate cross-hauling. At a relatively high level of aggregation (for example, 25 sectors), much cross-hauling will exist and is rational behavior. Also, LP models attempt to reduce the number of trade flows to minimize costs, hence trade flows will be seriously underestimated.

- Gravity Models: The rationale underlying the gravity approach is that the spatial movements of goods is directly related to the level of demand in the region of destination but is inhibited by the friction of transport cost. This approach has the advantage of reflecting the impact of changes in transport service. Also, the format of the model is flexible and its adequacy can be evaluated through statistical tests. However, this model also can only be applied in distribution over regions of the already estimated values of regional production and final demand. Gravity model techniques are often employed in economic analysis; here, they are used to reallocate interregional traffic following transportation network changes.

Other Analytic Impact Models

In addition to the general equilibrium analysis models already discussed above, there are a sufficient number of occasions where "partial equilibrium" models are appropriate and useful. For example, there have been a number of analytic models of changes in modal split, resulting from regulatory changes, which range over a fairly wide scope of variables, permitting users to make sensitivity tests of different policy variables.[19] These models, by most standards, are likely to be fairly large-scale, i.e., requiring (at least) several person-months to create and operate, involving many interacting variables, sizable data bases, and fairly complex (ordinarily, simulation) programs. These are typically "flexible" in the sense that they are less tied to the foundation of economic theory and the concepts of general equilibrium.

Empirical Results

In a review of a great deal of literature attempting empirically to link all types of public investment--transportation and other--to their economic development consequences, Roger Vaughan summarizes the few results which have utilized econometrics.[20] The work consistently referred to by Vaughan and other reviewers is more than ten years old,[21] has not been updated, and has had no counterpart study since. The CONSAD study did find causal relationships between certain transportation facility development (e.g., highways, barge facilities) and longer-run economic development--but in a relatively weak and complex way. Combinations of public works (transportation and non-transportation) seem to be required, not merely one or the other alone.[22]

Concluding Remarks

This paper has sought to identify how the economic development consequences of transportation system performance can, and in the future might, affect executive decisionmaking. It is oriented toward public policy at the Federal level but there are implications for other public echelons and for the private sector also.

There, certainly, is no unanimity of view concerning the efficacy and feasibility of building and using large-scale transportation/economic development models, or even combinations of large- or smaller-scale models. Somewhere in between these extreme opinions are the greater numbers of those of us who are faced with the realization that the complex decisions which have to be made, in an even more complex world, require the use of many aids, including sophisticated computer algorithms.

I believe slow--too slow, to be sure--progress is being made. Several ongoing research projects will make significant contributions, both to the models and data bases and to our empirical knowledge of transportation economic development relationships. I look forward to this improved understanding. Without it, I believe we are very likely making poor, perhaps dangerous and wasteful choices between important transportation system options.

Acknowledgement

I am indebted to my colleagues at CONSAD, particularly Dr. Donald Matzzie and Mr. Edward Malloy, for graciously sharing thoughts and concepts with me during the preparation of this paper; naturally, all misstatements are my responsibility.

EXHIBIT I

CONCEPTUAL DIFFICULTIES: TRANSPORTATION SYSTEM-DEVELOPMENTAL RELATIONSHIPS

- The transportation "industry" is quite heterogenous, supplying a wide-range of services, at diverse prices, to a wide industrial base.

- Since transportation is a heavily-regulated industry, the values inherent in changing service levels are not necessarily reflected in its rate structure.

- Determining an aggregative demand vector for "transportation" is difficult in the absence of a theory of the value of transportation.

- It is difficult to measure the productivity of the factors of production used in "the transportation industry." There is a good deal of "jointness" in the uses to which transport resources are put--together with other resources--in order to produce usable outputs.

- The utilities, or satisfaction, assigned to place and time values produced by transportation systems are related to human and production system behavior which are, at best, ill-understood.

- The units in which outputs are measured are not (typically) related to increments used in private and/or public decision processes.

- The "health" of the economy promoted and developed through the transportation system may be reflected less by the services used than by the fraction of the total potential of transport-feasible movements which are actually made.

- Transportation movements and their cargoes are not measured routinely, even on a sampled basis. These include non-regulated motor carrier, air freight, and much inter- and intra-city highway travel.

EXHIBIT II

TECHNICAL ISSUES TO BE RESOLVED IN MODELING

- Most transportation sectors are not either perfectly competitive or purely monopolistic; instead, they are characterized by various degrees of monopolistic competition and/or oligopolistic structures, which are difficult to analyze using the type of input-output models currently in use.

- Impacts are typically computed at national and, much less often, at major regional levels. Few modeling systems deal effectively with differential "distributional impacts" accruing to individual modes, localities, productive factors, population subgroups, and subregions.

- Typically, these models portray what occurs at the end of a process; transitional short-run consequences tend to be ignored.

- Most analytic models treat transportation services as a homogenous good, i.e., a standardized "output" measure, such as ton-miles. More realistically, there is a large number of transportation suppliers--modal and multimodal--providing differential transportation (of different quality dimensions) at a varying range of rates, causing shippers to incur differing total shipment costs (i.e., including time-in-transit, reliability of delivery, damage costs, holding costs, etc.).[18]

- Few, if any, of these models deal effectively with transportation regulatory policies which impact directly or indirectly upon health, safety, and environmental costs of performing transportation services, as well as the degree to which the system can provide certain services (e.g., regulatory policies governing entry, routes, abandonment, merger, and consolidation, etc.).

- Transportation costs are typically oversimplified in such models. Such treatment has a counterpart in the modeling simplification of how the "supply" of transportation is altered. Whereas in the "real world," carriers will--to an extent--alter service patterns as shippers' needs and the operation of other models change, little or no attention is paid by modelers to such induced transportation changes. The behavior of transportation firms is, for all intents and purposes, ignored in these models.

NOTES

1. Wilbur A. Steger, "Transportation Output Measures: Needs for Decision-Making," *Transportation Research Forum Proceedings: Seventh Annual Meeting* (1966), pp. 49-65; also, Joseph L. Schofer, "Emerging Methods in Transportation Evaluation," *Emerging Transportation Planning Methods* (U.S. Department of Transportation, 1978), pp. 53-96.

2. Wilbur A. Steger, *Ibid.*; George Wilson, "On the Output Unit in Transportation," *Land Economics* V (1959): 35; Harold Barger, *The Transportation Industry, 1889-1946* (National Bureau of Economic Research, Inc., 1951); J. E. Snell, "A Framework for the Analysis of Urban Transportation Research," (Evanston, Illinois: Northwestern University, 1965), pp. 38, 52-54.

3. U.S. Department of Transportation, *National Transportation Trends and Choices (to the Year 2000)* (Washington, D.C.: U.S. Government Printing Office, January 1977); National Transportation Policy Study Commission, *National Transportation Policies Through the Year 2000* (Washington, D.C.: U.S. Government Printing Office, June 1979); K. H. Schaeffer and Elliott Sclar, *Access for All, Transportation and Urban Growth* (Baltimore, Maryland: Penguin Books, 1975); and Roger J. Vaughan, *Public Works as a Countercyclical Device: A Review of the Issues* (RAND Corporation Report, R-1900-EDA, July 1976).

4. Roger J. Vaughn, *op. cit.*, p. v. These effects are relatively easier to trace at the national level as payments for domestic factors of production. At the regional level, they are a function of interregional interindustry linkages that determine the proportion of local productive inputs in the region.

5. A caveat: I do *not* include, under "economic development impacts," a number of short-run countercyclical consequences, e.g., increased utilization of idle capital and labor, including both the unemployed and the underemployed, at both national and regional levels. This exclusion also includes impacts upon short-run cyclical behavior in input markets, such as upon materials utilized in transportation investments, and involuntarily unemployed construction workers. However, in so doing, I do *not* exclude impacts of a *long-run* cyclical variety, i.e., those which economists consider to be more *structural* in nature. There is, admittedly, a somewhat fine line between what is and what is not included. However, there is a good deal already published about the short-run cyclical impacts, and neither technically nor substantively, can these be considered important in an economic *development* sense, since these effects are by and large only temporary in nature.

6. Section 4.0, as does this paper, focuses on freight transportation and industry as the core of economic development. While not discussed here, similar arguments can be made regarding an area's personal transportation systems.

7. See, for example, "Mechanics of the Urban Base," Techniques of Urban Economic Analysis, R.W. Pfouts (ed.) (New Jersey: Chandler-Davis, 1960).

8. CONSAD Research Corporation has been extensively involved with the Federal Railroad Administration, the United States Railway Association, railroads, communities, and state governments, with issues of rail line abandonment and rationalization.

9. CONSAD Research Corporation, Effects of Railroad Abandonment on the Modal Distribution of Traffic and on Related Costs (U.S. Department of Transportation, 1977).

10. CONSAD Research Corporation, Effects of Railroad Abandonment..., Ibid.

11. Adapted from CONSAD Research Corporation, Designing a Study of Motor Carrier Entry and Regulatory Reform (Interstate Commerce Commission, 1978).

12. Ann F. Friedlaender, "Issues in Evaluating Transportation Regulation," in Transportation Research Forum Proceedings (1975), p. 131.

13. While the study of general equilibrium systems can be traced back, ultimately, to a variety of eighteenth and nineteenth century theorists (e.g., the Physiocrats, Walras, Jevons), the first operational approaches appeared in the mid-1950s, based on computational concepts developed independently in the United States and the Soviet Union (Drs. Leontief and Kantaravich, respectively). W. W. Leontief, et al., Studies in the Structure of the American Economy (New York: Oxford University Press, 1953); see also, F. T. Moore and J. Petersen, "Regional Analysis: An Interindustry Study of Utah," Review of Economics and Statistics 37 (1955): 368-383.

14. "The Stability of Interregional Trading Patterns and Input-Output Analysis," American Economic Review 45, no. 5 (December 1955); see also Leon N. Moses, "A General Equilibrium Model of Production, Interregional Trade, and Location of Industry," Review of Economics and Statistics 42, no. 4 (November 1960).

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Scenarios for Federal Transportation Policy: Freight Policy Models (Cambridge, Massachusetts: Center for Transportation Studies, MIT, February 1978); Stephen H. Putman, et al., Interrelationships of Transportation Development and Land Development (Philadelphia, Pennsylvania: Department of City Regional Planning, University of Pennsylvania, 1973, 1976); Richard J. Olsen, et al., MULTIREGION (Argonne National Laboratory, U.S. Department of Energy, 1977); Clopper Almon, Jr., et al., 1985: Interindustry Forecasts of the American Economy (Lexington, Massachusetts: D. C. Heath, 1974); Faucett (Jack) Associates, Inc., Department of Transportation Input-Output Model: Summary and Computer Manual, Report to the Office of the Secretary, Office of Systems Analysis and Information, (Silver Spring, Maryland: Office of Systems Analysis and Information, 1970); Curtis C. Harris, Jr., Urban Economics, 1985: A Multiregional-Multiindustry Forecasting Model (Lexington Books, 1973); Karen R. Polenske, Study of Transportation Requirements Using National and Multiregional Input-Output Techniques, prepared for the Office of the Secretary of Transportation, Department of Transportation, (Washington, D.C., CFSTI: PB 174 742 April 1967); and Karen R. Polenske, Interregional Analysis of U.S. Commodity Freight Shipments, DOT Report #3, paper prepared for the Society of Automotive Engineers Meeting, Detroit, Michigan, 27 February 1974.

16. The references are to the authors and titles in the immediately preceding footnote.

17. This should not be taken to mean that these technical issues are not being researched; indeed, these are issues straining the "state of the art" and, consequently, many are being thoroughly investigated.

18. Wilbur A. Steger, "Transportation Output Measures: Needs for Decision Making," Transportation Research Forum Proceedings (1966), op. cit.

19. K. D. Boyer, "Minimum Rate Regulation, Modal Split Sensitivities, and the Railroad Problem," Journal of Political Economy (1977): 493-512; K. D. Boyer, "Estimating the Price Elasticity of Demand for Freight Transportation," (East Lansing, Michigan: Michigan State University, June 1976); and D. W. Woods and T. A. Domencich, "A Competition Between Rail and Truck in Intercity Freight Transportation," Transportation Research Forum Proceedings (1971), pp. 257-288.

20. Roger Vaughn, Public Works as a Countercyclical Device, op. cit., pp. viii-ix. The first technique, using materials requirements and input-output, is not typically used to estimate, empirically, ex post causal effects on one control variable or another.

21. CONSAD Research Corporation, A Study of the Effects of Public Investment (U.S. Department of Commerce, 1969).

22. Recently, conflicting evidence as to the long-run effects of interstate highways, James P. Miller, "Interstate Highways: Influencing Rural Jobs?", *Rural Development Perspectives* (March 1, 1980), pp. 35-39 indicates that, during the 1970s, there has been more rapid growth in *noninterstate* counties than in those with interstate systems. Similarly complex findings are described in CONSAD's recent four-volume Congressional/Commerce study on public works investments since World War II: *Final Report: A Study of Public Works Investment in the United States, Executive Summary;* volume I: *Historical Analysis of PWI Trends and Financing Mechanisms;* volume II: *Analysis of Maintenance, Condition and Financing of Urban Capital Stock;* volume III: *Effects of Federal Capital Grants on Five State-Local Functions*; and *volume IV: Appendices* (prepared for the U.S. Department of Commerce, March 1980).

TRANSPORTATION AND ECONOMIC DEVELOPMENT: THE GROWING SIGNIFICANCE OF THE TRANSPORT SUBSIDY ISSUE

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Abstract

The Province of Alberta is a North American example of a rapidly developing economy. Population and exports of bulk materials both promise to double in the next quarter century. Processing and secondary industry will grow even more. Much of the infrastructure to support this growth does not yet exist. The government faces pressures to expand both the highway network and railroad capacity so as to permit the development to occur. Because Alberta is separated by such large distances from major world markets, overall production costs must be minimized if the delivered price of its products is to be competitive. The role of the Tranportation Services Branch in the Department of Economic Development in supporting government development objectives is described. An early concern of the Department has been the long run economic impact of government investment in transportation, both expenditures and revenues foregone.

Government investment significantly influences the price and quality of service of the various transportation modes. A major effect has been to lower the price and improve the quality of road transportation relative to rail. The consequences include: diversion of profitable traffic from railroads and transit; underutilization of existing rail infrastructure; under-investment in new rail and transit services; land use developments that preclude economies of scale in transportation and other functions; an accumulating, unfunded government obligation to future roadway maintenance and replacement expenditures; demands for countervailing subsidies to formerly unsubsidized modes; and a social and economic commitment to petroleum intensive transportation in the future. The principal, but not sole financial advantage of roadways, is the omission from public accounts and prices to users of capital costs, both depreciation and opportunity cost of capital. Traffic diversion results because all costs, including capital costs and taxes, must be borne by rail customers but not by road users. Because of the depressing consequences for economic development of present policies, increased attention to road subsidies and policy alternatives is recommended.

Introduction

Economic development requires good quality access to markets, locally, nationally, and internationally. For an economy to thrive, the transportation network affording this access must be modest in its demands on resources, especially those in limited supply. A sensitivity to this linkage between transportation and economic development prompted the provincial government of Alberta to locate a Transportation Services Branch in a new Department of Economic Development created in 1979. Some of the activities and concerns of the people in this enterprise are described in the following paper.

Alberta and Economic Development

The Province of Alberta has a land area approximately equal to that of Texas. Bounded on the west by the Rocky Mountains and the Province of British Columbia, Alberta stretches northward from Glacier National Park and the Montana border some 750 miles to the Northwest Territories. Except for the two principal cities, Calgary and Edmonton, which number approximately 600,000 each, the province is sparsely populated. Its total 1980 population of 2,100,000 is approximately the same as that of Greater Baltimore, Maryland.

Two significant features of present day Alberta are:

1. the long distances separating it from markets and
2. the rapid pace of economic growth presently enjoyed and anticipated for the next 20 years.

Measuring from the capital city, Edmonton, the major markets are the nations of the Pacific Rim, linked through the port of Vancouver some 750 miles westward across the Rocky Mountains; and Central Canada, some 2,100 miles distant (to Toronto) across the prairies. There is little north-south goods movement other than imports of foodstuffs, meat, and manufactured goods. East-west surface traffic,including resource exports to the U.S., is carried over two major rail lines, two main highways, and various pipelines.

The historical economic base of Alberta was grain farming. Since the 1950s, agriculture has been supplanted by petroleum as the number one industry. Vast oil and natural gas fields have been successfully developed, while, more recently, synthetic crude is being extracted from extensive oil sands deposits. Large coal deposits in the Rocky Mountains also await exploitation. Export tonnage of bulk commodities is seen as doubling by the year 2000, while population is expected to increase by 50% during the same period.

Government must furnish supporting infrastructure such as water supply, schools, social services, and transportation to support this growth. A primary provincial objective is that development not be slowed by infrastructure bottlenecks. Two additional broad economic objectives are:

1. diversification into secondary manufacturing so as to maintain a healthy economy after the finite petroleum resources are depleted and

2. decentralization, such that growth is not concentrated solely in and around the two exisiting urban centres.

Transportation obstacles engender costs that can place Alberta producers at a disadvantage in distant markets. The long separation from marketplaces influences imports as well as exports. Imports as diverse as lettuce and neckties must bear the freight from place of origin. Coupled with long, potentially harsh winters, many elements of the cost of living become inherently expensive. For Alberta to be competitive, the entire society must function efficiently. All costs of production must be minimized so that the delivered price meets those of competitors who are more favourably located. Since Alberta is immune neither from the long run, upward trend in energy supply costs nor from the threat of interruptions to oil supply on the international scene, the pressures for greater efficiency promise to grow.

Transportation challenges of two sorts emerge from the combination of external environment and government objectives:

1. creating and maintaining an effective logistics channel for both bulk and processed goods, that is, one that is low in costs, adequate in capacity, and reliable;

2. facilitating personal access to social activities, including employment, in a manner that minimizes the resources used for mobility.

The high growth rate of Alberta creates a rare opportunity to take substantive action in these areas. Given present trends, some 50% of the dwelling units that will exist in Alberta 20 years hence have yet to be built. There is still time to shape much of the associated, supporting infrastructure, including transportation. Settlements that have yet to be built can, depending on public policy, be either profligate or parsimonious in energy consumption; benign or destructive of the environment; oriented toward safe modes of mobility or dangerous ones.

Transportation Activities of the Alberta Department of Economic Development

The Transportation Services Branch deals with all modes of transport, and its activities take a variety of forms. Its various directorates study basic transportation policy issues, undertake investigations of transport service problems, and seek to implement solutions. The Branch does not build roads or provincial airports, a major program handled by a separate department.

Policy research usually revolves around some aspect of the price and quality of transportation. Examples include cost-based versus value-of-service approaches to rate-making by carriers; elements involved in assuring the growth of economic activity in all parts of the province; reviews of institutional and regulatory matters; and new intercity public transport services for the middle class "choice" market to supplement the bus service used by the carless "captives" and the air service used by "expense account" business travellers.

Transport service investigations deal with specific or generalized movement problems, both freight and passenger. These will usually include all the elements of planning service improvement, including present and future demand, present carrier (public or private enterprise) performance, facility requirements, institutions, and finance. In a particular situation, one element may predominate. Examples of service investigations include a commodity ("slurry") pipeline from Alberta to the Pacific coast; new applications of the containerization concept; the feasibility of a high speed rail passenger service between the two major cities; and evaluation of the transportation element in regional land use plans.

As noted above, the Department neither operates nor builds facilities or services directly. Implementation of solutions may come about through negotiation with carriers; through provision of funds to acquire rolling stock or facilities; or through assistance to other agencies in obtaining funds to do a certain job. Examples include purchase of 1,000 grain hopper cars for use by the railroads in hauling Alberta agricultural products; the provision of financing to a shippers' consortium to buy and upgrade a bulk commodity terminal in Vancouver; and creation of a public corporation to own and operate major inland grain terminals.

The work program for the Branch spans a wide range of modal and user problems and extends from the conceptual and macro levels to implementation of specific services or multi-party agreements. As diverse as the issues are, certain themes recur. The following section deals with one such theme: the role of direct and indirect government subsidy on transport price and quality.

Indirect Subsidies: The Hidden Costs of Capital

The existence of direct, cash subsidies to certain transport services is well known in Canada and the United States. For example, annual public monies being expended or requested for urban transit, intercity passenger trains, and rural freight services are growing rapidly and are perennial subjects for legislative concern. Less well known, however, is the fact that these cash subsidies are dwarfed by the indirect subsidies that arise from the public provision of transport facilities ("infrastructure") at less than cost.

Indirect subsidies in transportation are important for several reasons. First, they impart bias to the transportation sector, causing traffic to divert from the unsubsidized mode to the subsidized mode. Second, capital investment in the unsubsidized mode, is cut back as the cumulative result of losing traffic to the subsidized mode, hindering modernization and improvement and leading to a relative decline in service quality and further loss of traffic. . Third, locational decisions in other sectors (residential, industrial, and commercial) come to be biased toward reliance on the subsidized mode, leading to still further traffic shift. The consequent diminution of service by the unsubsidized mode eventually reduces the choices available to consumers.

The principal issue is roadways versus railways. It is especially critical during the current period of increasing real price and uncertain supply of petroleum, on which road transportation is, at present, entirely dependent.

Rail transport, by contrast, inherently requires less fuel in many applications and can be operated by electricity generated by energy sources other than petroleum.

Great differences prevail between standards used to evaluate financial commitments to road transport and those used in rail. Rail investments are made in a market setting, modified in certain ways by tax laws and by government subsidies for unprofitable services deemed desirable in the public interest. To survive in the financial marketplace, railroads must charge rates high enough to generate after-tax revenues that cover:

- depreciation on physical plant sufficient to maintain that plant and
- a return on capital that is considered competitively acceptable in the financial community.

All rail expenditures and accounting procedures must adhere to the discipline of the marketplace. Among the railroad expenses that revenues must cover are traffic control, security, maintenance of way, plowing snow, terminals, yards, and accident investigation.

How different is the case for road transport! Almost the entire infrastructure of public roads is owned and operated by government. For the most part, the only costs that are recognized are cash expenditures for construction and maintenance. In those instances where construction has been financed by general obligation or revenue bonds, a return on capital is recognized; but it is at a subsidized (tax-free) rate of interest, not a market rate, and is reckoned in historical rather than constant dollars. Depreciation, either on book value, or some basis that reflects inflation, appears nowhere on the relevant accounts.

Charges made to road users--fuel taxes, registration fees, and ton-mile taxes--differ from one jurisdiction to the next, but are usually applicable primarily to the spinal highway system. Scarcely any user charges are applied to the vast network of feeder streets and roads. By 1980, many jurisdictions found that the user payments had become insufficient even to maintain the spinal highways against the combined ravages of time and traffic.[1] In brief, customer payments for use of the government furnished road network are only applicable to the core of that system; currently, they are barely adequate to maintain that core. Maintenance of the remainder of the system is funded by general revenues.

Road maintenance is not the only cost of road transportation. There is traffic control (traffic signals and police), street cleaning, snow plowing, lighting, security, special medical and public safety facility, equipment, and personnel associated with road accidents, net costs of traffic courts and appeals, and administrative costs to local government. Portions of these costs would be incurred if road transport as we know it existed or not. The point is that the majority that are chargeable to road transport are borne by the general funds of one level of government or another.

In brief, rail customers must pay sufficient amounts to cover capital, maintenance, and operating costs of infrastructure (plus property taxes on the infrastructure and the costs of the trains themselves). The evidence suggests that road users currently pay less than the full operating and maintenance costs of the infrastructure, none of the capital costs, and, of course, no property tax. To estimate the maximum fraction of infrastructure costs paid by road users, the authors endeavoured to compute the fraction made up by maintenance and operations in the Province of Alberta. Total road costs were computed in constant dollars using provincial highway data and data published by Statistics Canada, a federal agency. Depending on the assumptions made regarding cost of capital (10.1% or 15.5%) and depreciation, maintenance and operations expenditures amounted to 28% to 33% of total roadway infrastructure costs, approximately 1/3.

While details would differ from one jurisdiction to another, the 1/3 fraction is submitted as a valid, generalizable approximation. Given the prevalence of deferred maintenance and the fact that many maintenance and operations costs are and historically have been met out of general revenues, the fraction of total infrastructure costs borne by users in North America may fall well shy of 1/3.

Over the years, there has been extensive debate over the "true" extent of road subsidies. Highway backers have argued that no subsidy existed because highway expenditures were counterbalanced by revenues from fuel taxes and registration fees. Opponents argued that highway cash budgets did not tell the whole story, that motor vehicle operators should also bear the costs to local government and some capital costs and, in addition, be taxed on spillover disbenefits such as pollution and congestion.

For purposes of analysing intermodal impact, the operational definition advocated herein is conceptually simple. Costs should be tallied in a manner that is consistent among modes. Roadway costs, by this definition, include all items that correspond to elements in the rail cost base and that are reflected in rail prices; furthermore, road items should be computed by the same rules--the same effective cost of capital, for example. The excess of costs to government over revenues from transportation charges to users is the subsidy.

Economically, there is no question that cash budgets of highway departments. understate costs to government. In the first place, costs to local government are omitted. In the second place, the capital costs, depreciation and return on capital, are omitted. These costs are just as real in the public sector as in the private sector, whether they appear in public accounts or not. The old West Side Highway in New York City and various "closed to traffic bridges throughout the United States are convincing examples that physical assets owned by the public do depreciate. California's Proposition 13 in 1978 and parallel taxpayer rebellions elsewhere reflect both the fact and the belief of the electorate that public funds cannot be treated as cost free.

Efforts are being made in some jurisdictions to reckon the capital costs of government infrastructure with minor differences from the definitions advocated herein. In the United Kingdom, at government direction, the British Airports Authority has not merely made an effort to include in its charges capital costs--depreciation, return on capital, and opportunity cost of land--but has endeavoured to correct for inflation while doing so.[2] Similar concerns about infrastructure cost recovery for roads and their impact on railroads have been expressed in France and Switzerland.[3]

The Canadian Government Ministry of Transport has calculated capital costs of government furnished infrastructure for all modes during the 1970s. The latest published figures for 1975 show the losses on Canada's road system to amount to some $2 billion, with the percentage of costs recovered through user fees registering 58%.[4] Preliminary indications from more recent data are that the losses are climbing and cost recovery falling.

The authors have been unable to find comparable data (road revenues compared with costs of maintenance, operations, depreciation, and return-on-capital for all levels of government) for the United States. A common conversion ratio for economic affairs between the United States and Canada is 10:1 (based on population). Using this ratio, the American road deficit would have been in the order of $20 billion per year (1975 dollars). Given the flattening of road revenues in the United States and the impact of inflation, the corresponding number for 1980 may have been as high as $50 billion (1980 dollars).

Consequences of Indirect Subsidy

Past History of Modal Shifts

Almost every history of transportation relates how the construction of good intercity roads, starting after World War I, permitted trucks and buses to underprice railroads on high valued freight and on passenger services. As the decades passed and the road network expanded, so did the inroads into rail traffic. Many institutions of the 1930s disappeared--most passenger trains, mail cars, milk runs, Railway Express, to name a few. In urban areas, a similar phenomenon occurred with once profitable public transit companies, whose riders were increasingly captured by the convenience and perceived low cost of the automobile.

With profitable traffic lost to road vehicles, rail and transit profits diminished or disappeared. In the absence of profits, funds to replenish capital were no longer forthcoming. The fixed plant and the rolling stock deteriorated, as did the quality of service. As service deteriorated, governments responded to public pressure to expand and improve the roadway alternative.

Government subsidy undoubtedly played a role in enabling public and private road carriers to underprice the railroads and to hold down the perceived costs of automobile operation; however, many other influences were present. Government regulation mandated service on unprofitable lines. Many a rail and transit company fell into the hands of management who "stripped the assets" by draining cash off for other enterprises or for dividends. Finally, rail and transit suffered as labour-intensive industries during a period of rising prosperity. As productivity in other parts of the economy climbed, so did prevailing wages in all industries. Productivity lagged in rail and transit;

their costs climbed faster than prices in the rest of the economy. As costs climbed, ability to compete declined.

In brief, several economic forces were working to curtail rail and transit service in markets where they were weak. Some modal shift was inevitable even if there had been no government road subsidies. Nonetheless, these subsidies accelerated the process and, with their cumulative impact on capital formation, caused the decline to be greater than it would have been otherwise.[5]

Land Use

Contemporaneous with the growth of the motor and highway industries and the demise of transit and rail service, came the sprawling scattered suburbs. Again, many forces besides government road subsidies contributed to the process: federal housing and tax policies, social pressures, and fiscal mercantilism, whereby suburban jurisdictions sought successfully to avoid the financial burdens and proximity of low income residents in neighbouring jurisdictions.

In the post World War II suburbs and communities, single family homes were the norm and zoning to separate social activities from one another became routine planning practice. Everything was separated from everything else by distances too long to be traversed on foot. Activity centres came to be so randomly scattered over such large areas that ride sharing, by transit or private vehicle, became increasingly difficult. Much transit literature of the 1970s has explored this trend.[6] More recently, energy conservation literature has highlighted the extravagance in energy consumption of both the single family dwellings of suburbia and the transportation energy--currently petroleum-required to keep it functioning. As this literature points out, the low density, detached dwelling urban form prevents economies of scale in insulation, air conditioning, co-generation, and collective heating.[7]

Another aspect, yet to be investigated in-depth, is the impact that extensive highway construction has had on exurban location of industry and new, low density towns and cities. In the days of underpriced roads and inexpensive petroleum, one highway interchange was as accessible as the next by private vehicle. The lure of cheap land has led to the establishment of factories and warehouses on open land, miles from existing cities; employees take up residence in formerly rural towns and villages. In some areas, the scatter has become so great as to cause the decline of intercity common carriers by bus, air, and truck. It is becoming difficult to build up financially attractive load factors. Rail service is not even at issue; if load factors are too low for road vehicles or airplanes, using publicly furnished infrastructure, rail service, with its requirement to cover roadbed costs, is out of the question.

In brief, road subsidies have contributed to a pattern of land use that is profligate of energy. Not merely have economies of scale in transportation become impossible (without sacrifices in convenience) but so have economies of scale in other aspects of residential, commercial, institutional, and industrial resource consumption. The United States has invested in a social-economic infrastructure that is inherently inefficient in resource consumption and Canada is following suit.

Pressure for Countervailing Subsidies

Over the years, services by once profitable transit and railroad enterprises deteriorated in the face of competition from road vehicles travelling over government furnished infrastructure and as a result of the concomitant land use developments. Faced with loss of service, businesses and residents dependent on these modes for access have sought government aid. A patchwork of subsidies and government takeovers has evolved.

Urban transit firms were the first to succumb. AMTRAK and CONRAIL are manifestations of the same phenomenon in railroading, as are rail branch lines subsidized or owned by governments. More recently, unprofitable regional bus services, especially in suburban commute situations, have increasingly converted to subsidized, government operations.

These subsidies, which are in a highly visible cash form, stimulate such debate despite the fact that their total sum is but a small fraction of the indirect subsidy going to competing road transportation. The persistence of the cash subsidies reflects the size of the constituencies to which these modes are valuable. In a sense, the cash subsidies are a countervail to the indirect road subsidy, a countervail necessary to preserve freedom of choice in a marketplace greatly distorted by government action. How much countervail would be necessary if the indirect subsidies were eliminated is a matter for speculation.

Access versus Mobility: Misleading Measurements by Planners

In their consideration of transport policy options, elected officials rely in some measure on advice from professionals regarding what consumers want. The professionals oblige by measuring what consumers do. The logic is that consumer behaviour in the marketplace properly reflects consumer preference. The marketplace itself has been distorted somewhat by government action, as discussed above; in addition, significant errors are common in the usage data that influence decisionmakers.

The gist of these errors is that the modal share of private motor vehicle (automobile) travel tends to be overstated.[3] For example:

- All vehicle trips by automobile are counted by a blend of cordon counts, traffic counters, and proxies such as gasoline consumption. Not all trips by public means are counted. School buses, special buses to employment centres, and other bus transport by firms that are not members either of transit or intercity bus associations are usually overlooked.

- Person trips by automobile are overstated because neither trip counts nor occupancy ratios are corrected for chauffeured trips. When young or old are chauffeured, for example, many more person trips are logged by automobile than if they make the same trip by bus.

- Walking trips are usually omitted altogether. For urban trips under a mile in length, walking trips are very significant.

The exclusion of the pedestrian mode from transportation planning is of particular concern because of the interactions with land use and transit planning. It arises, in the authors' view, from a confusion of ends and means in transportation planning. The end, or objective, is that people have access to social activities. Travelling by vehicle from one activity to another is an unfortunate necessity; the activities are too far apart for people to walk between them. So long as policymakers receive information only on trips by vehicle, and misleading information at that, they are encouraged to focus on the voyage rather than its purpose: to achieve access to activities. A strategy emphasizing efficiency would be "to achieve access with a minimum of vehicle trips."

Surface Transportation and the Looming Capital Squeeze

The world promises to be capital-short during the next several years. New sources of energy all promise to be capital-intensive. So will the measures required to reduce energy consumption or to switch from one source to another. In the Western world, especially North America, the industrial plant, housing stock, urban infrastructure, and transport networks all need infusions of capital for modernization. The resulting demand for scarce resources is likely to cause continued inflation or high interest rates or both. The capital starved nations of the Third World will be especially hard hit by the resulting capital shortage. International tensions are likely to increase and lead to heavy capital commitments for military purposes.

Sound planning in the near term future must acknowledge the high probability of climbing energy costs and a continuing, tightening capital shortage. It is difficult to see how the upward trend in disposable personal income of recent decades can be maintained. Disposable income will probably fall in industrialized societies that do not seek productivity improvements in all sectors, including transportation.

Transportation productivity can be increased by economies of scale and by reducing the need for movement by vehicle. In practice, this means an emphasis on rail transportation for freight, and on transportation and land use policies that maximize the potential for walking and for ride sharing, be it car pooling, buses, or trains. Those societies that achieve these economies will be the strongest in the next century.

Where to From Here?

One of the requirements in setting a future course of action is to understand how one arrived in one's present predicament. Another is to learn what choices are open. Calculation of road and other indirect infrastructure subsidies would illuminate both issues. If roadway deficits are as great as implied above, and if the projected trends for their future growth are accurate, then the sooner decisionmakers become aware, the better.

The question of government investment policy in transport is a recurrent theme in the work being undertaken by the staff of Alberta Economic Development. The authors hope that by drawing attention to the issue, they will contribute to two goals:

1. a better understanding of the resource needs and performance of various transport solutions by professionals and elected decisionmakers;
2. the generation of data, uniform by mode, that will enable us all to make better decisions.

The opinions expressed herein are those of a personal professional nature and are not necessarily coincident with policies of the Government of Alberta.

NOTES

1. Lloyd G. Byrd, "Deferred Maintenance - Opportune or Optimum Strategy?" Public Works 112, 1 (January 1981): 66-67.

2. British Airports Authority, Annual Report and Accounts 1979/80, London, pp. 50-53 and p. 73.

3. Alain Rathery, "Some Recent Thinking on Freight Transport Pricing in France and Switzerland," Journal of Transport Economics and Policy, (January 1979): 44-51; See also A. Jennings, "Infrastructure Pricing and the E.E.C. Common Transport Policy," Journal of Transport Economics and Policy (May 1976): 180-181 and 194.

4. Ziss Haritos, "Transportation User Charges: A Federal Perspective," paper presented at the Canadian Transportation Research Form Conference, Ottawa, Canada, 1979.

5. In both Canada and the United States, the federal governments furnish both direct and indirect subsidies to aviation and water transport; state, provincial, and local governments also subsidize aviation. These subsidies have worked to the detriment of rail service in the same manner that road subsidies have.

6. Robert R. Piper, "Trends in Energy Supply and Policies for Urban Mobility," Proceedings, Transportation Research Forum, 14, (1973).

7. W.R. Derrick Sewell and Harold D. Foster, "Analysis of the United States Experience in Modifying Land Use to Conserve Energy," report prepared for the Canadian Minister of the Environment, November 1979; See also "Energy Conservation Through Land Use Planning: A Synthesis of Discussions at a Symposium Held in Montreal, 26-28 March 1980," Working Paper No. 6, Environment Canada.

8. Brian E. Sullivan, "Some Failings in Today's Decision-Making and their Impact on Tomorrow's Urban and Regional Transit," paper presented at the Fourth UMTA Research and Development Conference, Norfolk, Virginia, November 1980.

PERFORMANCE CONCEPTS FOR MEASURING THE ROLE OF TRANSPORTATION IN NATIONAL ECONOMIC DEVELOPMENT

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Abstract

This paper identifies the links among transportation goals, policy, programs, program instruments, supply and demand, and system performance to evaluate the potential role of transportation in economic development. Effective leverage by government policy on development goals requires powerful leverage at each of these links, but experience has shown that such powerful leverage rarely exists. Furthermore, expansion of the transport sector today often conflicts with economic development goals, contrary to the historical experience of developed countries. Although the total effect of an advanced transportation sector is supportive of economic development, incremental changes in transportation system performance are not a powerful influence on development goals. The "Industrial Revitalization" issue is addressed in this context and some proposed solutions to our economic malaise are considered. For the most part, these are found wanting or unresponsive to the real problems. The paper closes with "dos and don'ts" for U.S. transportation policy. The principal theme is that eliminating many of the negative effects of present policy on economic development should take precedence over attempts to initiate a positive program to advance economic development through transportation policy. Good economic analysis of transportation projects and programs will generally account for most economic benefits of transportation improvements, and there are rarely any "downstream" economic development benefits that would justify otherwise economically dubious courses of action.

Introduction

The purpose of this paper is to examine the role of transportation in the national economic development (as opposed to site-specific impacts of transportation changes) of a Western economy with special emphasis on the United States. The paper makes the case that the role is quite limited in the sense of incremental opportunities not yet realized. Clearly, transportation is a vital sector in the U.S. economy. A substantially diminished role for transportation, such as would be occasioned by an oil embargo, would be devastating to the economy. But this fact does not necessarily imply that there is an important incremental and unfulfilled role for transportation as a "leading edge" in economic development. Rather, the best that can be done in today's

Western economies is to fashion transportation programs that apply the least friction to the achievement of economic development goals. At this date in economic history, we must consider the ancient rule of therapy, "first, do no harm."

The achievement of transportation goals requires strong sequential links among transportation goals, policy, programs, program instruments, supply and demand, and system performance. To apply transportation policy to achieve the goal of economic development assumes the existence of strong leverage at each of the links. Experience shows that effective leverage must be applied at every link if policy is to be successful. This paper addresses the principal reasons for the relatively weak links defining the role of transportation in economic development:

- There is often a weak relationship between transportation goals, transportation policy, transportation programs, and policy instruments.

- In addition, the links between transportation program instruments, transportation demand and supply, and transportation system performance are often weak because subsidies are the principal instrument used (among other reasons).

Equally important, the relationship between transportation goals and transportation system performance is not fully captured by simple linear links. The historic role of transport in achieving economic development has been to provide increasing mobility for people and goods at low cost. But today the role of transport has evolved so that expansion of transportation often conflicts with development in modern economies. This conflict, together with conflicts between the transport sector and those of other sectors (e.g., the national security implications of oil imports) imply that expansion of transportation programs has incremental consequences that are not supportive of economic development and are very often diametrically opposed to economic development goals.

These principles may be seen in two of the most important developments in transportation in the United States. The first is the strong move towards regulatory reform in transportation. The second, induced by both government fiat and private sector self-interest, is to increase auto fuel economy. The first is an effort to undo the perceived harm of government policy on the transportation sector. The second is an effort to undo the perceived harm of the transportation sector on the economy and national security. In neither case is transportation a positive "leading edge" in fostering economic development, as was so fashionable as a transportation policy goal during the highway construction boom of the 1950s and 1960s and the transit construction boom of the 1970s. Yet, both the regulatory reform and auto fuel economy programs are widely regarded as two of the most successful Federal transportation program initiatives undertaken in recent years.

This trend is also apparent in that much of the economic concern with transportation programs is with the costs of achieving noneconomic objectives in the transport sector--implementation of 504 regulations, on accessibility for the handicapped, auto safety and emission regulations, Section 13C of the

Mass Transit Act, aircraft noise, truck size, and weight restrictions, etc. Most economic analysis regards trade-offs of economic costs with the social and political benefits of these programs. Rarely, do we hear of transport programs actually concerned with advancing economic development. Rather, the concern is with minimizing the costs for economic development in achieving noneconomic objectives in the transport sector.

Equally important is a changed perception of transportation. During the highway construction years of the 1950s and 1960s, increased mobility was clearly perceived as good, and induced travel was one of the estimated benefits of these projects. By the 1970s, it became obvious that one had better not find any induced travel if one wanted to maximize a project's chances of approval. In a resource scarce world, many even questioned whether economic development was a good thing and transportation goal formation responded to this changed emphasis.

The paper continues with a discussion of the relationship of transportation goals, policy, and programs. These links have received the greatest amount of research attention and will therefore be the major focus of attention. The issues are related to the recent discussion about "industrial policy" in the United States. The paper closes with policy recommendations.

Transportation Goals, Transportation Policy, and Transportation Programs

If national transportation policy is to pursue a coherent strategy for achieving national transportation goals such as economic development, there must be a strong link between goals, policies, programs, program instruments, and impacts on system performance. Unfortunately, the link between national transportation goals, policies, and programs is often extremely weak. While this weakness is rarely disputed, the reasons for the weakness are less clear.

One explanation is that every program is affected by a resolution of many contending forces. Any attempt to clarify and rank program goals is perceived to produce a needless requirement to set formal goals in concrete and to declare permanent winners and losers.

It may also be that programs, especially those that are ineffective in accomplishing their original objectives, often tend to be captured by new constituencies with new goals instead of being reformed in an effort to accomplish their original objectives. (How many of us remember the days when Federal mass transit grants were justified on the grounds of saving money, especially for hard-pressed local governments?)

A third explanation may be that the demand for transportation is a derived demand rather than a service which is consumed for its own sake. As Paul Roberts[1] has pointed out, this means that transportation policy must always be responding to final users for whom transportation is a means to an end. Transportation policies and programs must be flexible and informal if they are to respond to a constantly changing set of priorities and constituencies.

Nowhere is the problem better illustrated than in the deliberations of the various national transportation study commissions over the years.[2] As part of recent efforts by the National Transportation Policy Study Commission, I participated in a study at Charles River Associates (CRA) on the relationship between transportation goals, policies, and programs.[3]

This study revealed a number of interesting findings with regard to national transportation policy:[4]

- There is no overall "policy" which comprehends all modes, activities, agencies, and markets.
- Rather, policy goals are linked to specific programs and are established in statutory language or the Code of Federal Regulations.
- Programs in turn are associated with modes, and there are few incidences of goals or programs which deal in a comprehensive fashion with a particular market.
- Contending modal programs and policies overlap markets differently.

The CRA report goes on to conclude, based on an extensive review of transportation goal statements and program implementation, that:

> The statement of goals as broad generalities rather than as specific objectives, and the failure to establish explicit guidelines for trading off objectives make it impossible to assess the degree to which programs achieve goals. Indeed, our analysis suggests that programs, not goals, are the foci of policymaking, and that goals are added to programs rather than programs being devised to implement the stated goals. Goals are ornamentation for the structure of policy, not the foundation.

Part of the problem may be traced to the sheer magnitude of the number of conflicting goals. Where each program is expected to respond in part to a wide variety of conflicting goals, the problems of measuring effectiveness are obvious.

This problem is compounded by the tendency for programs' objectives to be enlarged to broaden the base of support for congressional funding. The proper achievement of a program's goals requires the concentration of resources where the problems and the opportunities for success are greatest, but the need for a growing constituency requires proliferation of objectives, constituencies, and programs.

Proliferation of goals also results because many transportation policies are implemented with subsidies. Generally, there is an excess demand for these funds, and the tendency is to put restrictions on the recipient as a means of equilibrating supply and demand. Additional constraints on recipients, often embodying objectives remote from the initial program objectives, will continue to be added until the stack of grant applications exhausts the available funds. Such conditions will often be remote from the original intentions of the programs, but may sooner or later become more important than the original objectives. Regardless of one's views of the guidelines on access to the handicapped in Section 504, can there be any doubt, that the most important policy issues today were not dreamed of at the subsidy's inception?

The proliferation of objectives may be seen also in the large number of goals that must often be evaluated in making policy decisions. As part of our research, we identified twelve broad national transportation goals. Further complicating the problem is that little agreement exists on how achievement of each of these goals should be measured, much less how weights for trading off goals should be identified.[5] In addition, these goals are now being accomplished by such a large number of programs that even veteran Washington observers are startled to see them listed.[6]

In short, we can summarize the problem of the relationship of goals, policy, and programs as follows:

Accountability - Goals are associated with programs, but programs tend to be narrowly focused by mode rather than market, violating fundamental management principles of accountability, authority, and responsibility.

Clarity - Goals tend to be stated vaguely and a program's goals evolve over time, making it impossible to concentrate resources effectively or to measure performance consistently.

Consistency - Programs often endorse a multitude of conflicting goals, often without explicit trade-offs, making the measurement of performance impossible.

Given the present policy and program environment, it is difficult to imagine entirely new programs with a well-defined constituency devoted to the goal of "economic development," or to imagine how "development" might be added to our list of transportation objectives to modify the implementation of existing programs in a meaningful way.

Even if these purely institutional obstacles to implementing a coherent strategy to use transportation as a tool in advancing economic development were not a problem, there is, of course, the issue of whether we have the will to do it. Transportation works best in promoting economic development when government policy is providing benefits, expanding service, and lowering prices. But when the problem is how to stop people from doing what they prefer, the task is much harder.[7] Yet, most of the credible ideas for contributing to economic development, such as elimination of wasteful subsidies, require penalties on the transportation sector.

A related discouraging impediment to pursuing economic development as a transportation goal is the limitations of subsidies in links 4 and 5. Since the principal means of promoting economic development through transportation programs is through subsidy, we must examine the suitability of the subsidy mechanism to its task. We now turn to that issue.

Transportation Subsidies and Economic Development

The role of transportation in economic development is limited because the principal mechanism for promoting transportation is the subsidy, and subsidies have substantial inherent deficiencies as a mechanism for promoting development.

A few years ago, the Joint Economic Committee (JEC), undertook a review of Federal subsidies.[8] Careful analysis of past transportation subsidy programs indicates that many have not been shown to pass any reasonable test of public interest, economic or otherwise. Despite the allocation of considerable sums of money, many programs often make an imperceptible impact on the objectives they were designed to accomplish. To the extent that the effects on income distribution or resource allocation can be determined, they are often inconsistent with the stated objectives of the subsidy's proponents. Many subsidy programs deliver most of their benefits to higher income families despite lip service to the needs of the disadvantaged. The economic incentives embodied in these programs, which are rarely considered in the legislative process, often distort resource allocation in our economy and produce a waste of economic resources.

There is a rather large and very critical body of literature on the shortcomings of specific transportation subsidy programs.[9] There is also literature in economics which justifies subsidies to transportation according to the three basic justifications (economics of scale, market imperfections, and externalties). The trouble is that these justifications have little to do with actual subsidies. The constituency of government is consumers and producers, not alternative allocations of resources, and the actual subsidy budget shows little resemblance to one that would be expected from economic justifications of subsidies.

In summary, subsidies are the principal policy instrument that comes to mind when the goal of economic development is advanced. But subsidies are not well suited as a policy instrument for achieving economic development goals. In many cases, the subsidy simply does not have a sufficiently large output effect to make a difference and the result is simply equivalent to an unrestricted block grant. In other cases subsidies encourage uneconomic expansion of the transportation sector to meet needs that could be met more efficiently by other means. They are far more likely to lead to waste and unintended consequences than to economic development. Experience, furthermore, does not give us assurance that future subsidy programs will not simply repeat the mistakes of the past. As Secretary Weaver, the first Secretary of the U.S. Department of Housing and Urban Development, once remarked to the author, the hardest challenge for any relationship is to test it by giving away money without corrupting the relationship.

Transportation and "Industrial Revitalization"

During 1979 and 1980, a lot was heard on the subject of "industrial revitalization," or "industrial policy." Much of it came from the U.S. Department of Transportation, perhaps because of the plight of the auto industry at the time[10] or because the proponents felt that transportation was ideally suited for a leading role in revitalizing the economy. But the key elements of thought apparently extended to the entire economy because proponents were concerned that the country's long-run economic strength was jeopardized by a combination of external threats (e.g., dependence on high cost and undependable sources of oil) and domestic economic weaknesses.

As the Carter Administration focused its attention on getting re-elected, this rhetoric gave way and was never followed up with anything specific (except money for Chrysler) during 1980. But the Reagan Administration has made the economy's plight a priority for its first year. Again, this raises the question of whether there is a special role for the transportation sector as a leading edge in economic development.

The vagueness of the "reindustrialization" doctrine makes it difficult to evaluate. The concept of "industrial revitalization" is something more than "supply-side economics" or "getting the government off the backs of the people." Nor is it simply another call for fiscal responsibility, lower taxes, and elimination of government waste. No, it is, at least in part, a call for the government to step in and correct management failure in industry.

Increased enthusiasm for "reindustrialization" policy is remarkable because it rejects a fundamental precept which has been long established in national economic policy. The private economy may have been charged with being unconcerned about issues of equity, environment, safety, etc., and the national economic policy should stabilize private sector economic fluctuations. But whether the private sector was incapable of meeting its principal responsibility of providing a high and rising standard of living and a base to finance an ever-rising level of government expenditures was never seriously questioned.

Some Proposed Solutions

Some of the proposed solutions to these problems, apart from the macroeconomic debate regarding monetary and fiscal policy, relate both to the transportation sector and industry in general. The proposed solutions[11] are:

- a "partnership" between government and industry;
- accelerated depreciation, tax credits, and other tax policies to encourage investment;
- changes in the antitrust laws to encourage industry-wide cooperation to compete against foreign products;[12]
- subsidies and other support for technological development; and
- loan guarantees and other financial support.

Review of the Proposed Policies

To judge these proposals, we must first review the record. First, the recent performance of the U.S. economy has been reasonably good, especially in light of the shocks of inflation, currency fluctuations, and energy price increases. The recent economic expansion was extremely long by historical standards and has generated significant numbers of new jobs.

There is alarm that the U.S. is not keeping pace with world trends in manufacturing and retaining its leading role as an industrial leader. The evidence indicates that while certain industries, such as steel and auto, face severe challenges, others are showing very strong performance. For example, strong performance by the aircraft and aerospace industries in 1980 reflected strong order books for commercial aircraft and defense spending programs. Furthermore, these industries are very labor intensive, causing favorable employment impacts relative to other industries.

The rhetoric of "industrial revitalization" does not comport with the facts. The facts are that the U.S. has been a strong performer in world markets. Exports of goods production has risen from 6.4 % of total U.S. goods production in 1970 to 13.5% in 1980.[13] Exports have been particularly strong in agriculture and transportation equipment. Despite the effects of fuel price increases, the U.S. balance of payments trade deficit showed an improvement in 1980.[14] Devaluation of the U.S. dollar has made America the low-cost seller in everything from Boeing jets (the number one U.S. exporting company) to tourism, and our export performance is showing this, if with a lag.

It is, of course, fashionable to point to examples of other economies, such as the Japanese, where the cooperation between government and industry is assumed to work wonders. The reason these examples are chosen is that our own record of government endeavor in this area is so weak. As we look back to our painful experience in the transportation sector, we see examples such as Conrail, the SST, AMTRAK, Transbus, People Movers, waterway investments, and rail transit as glaring failures of U.S. government support for investment and technological development. The government's record simply is not good enough at this point to warrant our confidence.

The earlier discussion of transportation policy helps explain the poor record of Federal involvement in developing the transportation sector by means of the type of solutions proposed by the adherents of reindustrialization. For example, distortions of original intentions of the program have undoubtedly contributed to many of the problems. Is there any doubt that the bold proposals of industrial revitalization will lapse into old fashioned protectionism of weaker industries? Instead of taking steps to insulate the U.S. economy from world competition, we should take steps to promote competition and freer trade. This effort should be focused on sectors of the economy where the United States has a position of strength, such as transportation equipment for construction, railroad locomotives, heavy trucks, and aircraft.

Efforts to develop the transportation sector by means of support for technology development seem to have had the least success of all. The reasons why the government sector seems to be poorly suited to make much of a contribution to research and development and product innovation may also be seen by observing the pros and cons of firm size as a critical success factor in innovation. Large firms often have the advantage of experience in every phase of product delivery (engineering, production, quality control, marketing channels, advertising). All of these are brought to bear on the development process at the proper time, if the process is managed correctly. On the other hand, smaller companies, although lacking the integration and depth of experience, can move quickly and are often dominated by innovative entrepreneurs who make things happen. By these measures, government usually lacks all of the attributes vital to success. Government services are poor training for development of these skills and, in any event, no enterprise can afford to depend on the government for truly significant innovation.

Recommendations

If there is little to be said for a special leading role for transport in achieving goals of national economic development, are there, nevertheless, appropriate policy recommendations? I am reminded of the little known, and perhaps apocryphal origins of the phrase laissez faire. When the French economic minister Colbert inquired as to what the French government could do to promote industry, the response from industrialists was, "leave us alone."[15]

Taking our cue from this advice, there is a decade of work ahead in simply dismantling the harmful effects of past policies on economic development by eliminating programs of little value and by correcting the errors in existing programs. When that is done, we could then turn to the needs of the industrial sector, if any.

Dos and Don'ts

Rising energy costs have taken their toll in the transportation sector. As a petroleum-intensive industry, transportation must focus on improved productivity and efficiency, reduced energy intensity, reduced growth in mobility, and enormous investment in more energy-efficient technology and facilities for the transportation of energy.

The greatest spur to productivity and efficiency is to continue maximum reliance on private ownership of carriers and to continue a policy of regulatory reform that gives carriers the flexibility they need to respond to the changing operating environment. The two most important success factors in the transportation sector will be marketing and financing. It will be the government's task not to deprive it of either.

Economic regulation seems to keep everyone happy in an environment of a rising economy, increasing demand, favorable technological change, and acceptable profits. In a stagnant or declining industry or with reduced productivity, regulators find it impossible to adjust downward. Two examples of such regulatory failure are the enormous losses incurred by the international air carriers during 1979 because of lagged regulatory response to fuel price increases, and the low profitability and enormous backlog of deferred maintenance resulting from failure of regulation to respond to a declining rail industry. We simply cannot rely on economic regulation to do the "dirty work" of making the user comply with the economic imperatives of a deterioration in the economics of the business.

In short, the transportation sector is in massive transition. Government regulation has had a poor record in managing adverse transitions, and management of transportation enterprises must be given the flexibility it needs with regard to price, service, and investment to make the transition. In a sense we are lucky because the costs of transition to a more fuel efficient transportation sector can be borne in part by eliminating government-induced inefficiencies in the system. If we are a sinking ship, at least we can be thankful we have so much that can be readily thrown overboard!

Major sectors of transportation, particularly air and rail, have operated over long periods of time at rates of return which are too low. Yet the transportation industry now faces massive needs for maintenance and rehabilitation of facilities, replacement of energy-inefficient technology, and construction of new facilities.

The most obvious recommendation for remedying this problem is to create an atmosphere of profitability that will encourage investment. Second, as noted above, we can no longer afford to indulge in wasteful subsidies and misguided transportation investments given the present capital requirements. When the net worth of an airline can be meaningfully equated to the cost overrun on a single rail transit extension, clearly, something is wrong with our investment priorities.

The immensity of this investment task may be seen by reviewing the need for major investments in rail and pipeline for energy transportation. The investment in the Alaskan gas pipeline will dwarf the rate base of the Lower 48. The TAPS project was comparable to the rate base of the domestic oil pipeline industry. As our consumption pattern of energy use changes, so will the requirements for significant transportation infrastructure. Potential development of entirely new transportation industries, such as coal slurry pipeline, is another example.

The magnitude of this investment task is a major challenge to the U.S. economy. Much of the needed investment is not a complement to labor and other resources to expand output but merely a substitute for energy. This large replacement and retooling effort will absorb a significant amount of resources.

In short, we can no longer afford a "business as usual" transportation policy. Economically vital investment projects can no longer take a back seat to economically dubious projects. Costly constraints on carriers' ability to manage the transition must be dismantled, and carrier profitability must be sufficient to encourage the massive requirements needed.

In closing, I would like to add that my paper is not a rationale for eliminating economic analysis as a key factor in transportation policymaking, nor is it a statement against increasing incentives for savings and investment, increased productivity, and "supply-side" economics in general. On the contrary, economics has received far too little attention in transportation decisionmaking. But there are rarely any "downstream" economic development benefits in other sectors of the economy that are not captured by good economic analysis of the transport sector. Rather than advance new initiatives with economic development in mind, we should settle for a strong dose of economic evaluation to minimize the economic drag of existing programs.

NOTES

1. Transport Tommorow (Washington, D.C.: National Chamber Foundation, 1981).

2. See, for example, National Transportation Study Commission, National Transportation Policies Through the Year 2000, Final Report (Washington, D.C.: Government Printing Office, 1979).

3. See Charles River Associates, Incorporated, National Policy, Goals, and Programs, prepared for the National Transportation Policy Study Commission (October 1977) and An Analysis of the Impacts of Selected Transportation Issues on National Transportation Goals (April 1978).

4. See National Policy..., pp. 1-2ff.

5. See, for example, Peter Self, Econocrats and the Policy Process: The Politics and Philosophy of Cost-Benefit Analysis (Boulder, Colorado: Westview Press, 1975), and Joseph L. Schofer, "Evaluating Transportation Alternatives," presented at Seminar on Emerging Transportation Planning Methods, sponsored by the Office of the Secretary, U.S. Department of Transportation, 5-9 December 1976, Daytona Beach, Florida.

6. The October 1977 CRA report required a 31-page appendix to list programs by market and mode affected.

7. For a detailed discussion of this phenomenon, see Alan Altschuler, et al., The Urban Transportation System: Politics and Policy Innovation (Cambridge: MIT Press, 1979), Chapter 2.

8. Joint Economic Committee, U.S. Congress, The Economics of Federal Subsidy Programs (Washington, D.C.: Government Printing Office, 1972).

9. See, for example, Joint Economic Committee, op.cit., Part 6--Transportation Subsidies

10. See "Remarks Prepared for Delivery by U.S. Secretary of Transportation Neil Goldschmidt at the Economic Club of Detroit," 15 January 1980.

11. For a discussion of these various plans, see the Congressional Record, in particular Jerry J. Jasinowski, Assistant Secretary of Commerce, "A New Industrial Strategy," Congressional Record-Senate (23 October 1979), S14975, and "The Case for an Industrial Policy," Congressional Record-Senate (28 September 1979) S13711, and Jimmy Carter, "Industrial Innovation-Message of the President of the United States," Congressional Record-House (31 October 1979), H10046. The "industrial policy" debate appears to be derivative of the "national economic planning" issue which became dormant when President Carter assumed office. For a discussion of the international dimension of these issues, see William Diebold, Jr., Industrial Policy as an International Issue (New York: McGraw Hill Book Company, 1980).

12. See, for example, Lester C. Thurow, "Let's Abolish the Antitrust Laws," New York Times 19 October 1980.

13. Paul W. McCracken, "A United States 'Industrial Policy,'" The Wall Street Journal, 12 January 1981.

14. "The Rise of American Exports," New York Times, 25 January 1981.

15. Robert L. Heilbroner, The Making of Economic Society (Englewood Cliffs: Prentice-Hall, Inc., 1968), p. 67.

A MODEL OF THE ACCIDENT PROCESS AS A TOOL TO DEVELOP INDICATORS FOR TRANSPORTATION SYSTEM SAFETY AND TRAFFIC RISKS

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Abstract

This paper deals with the development of indicators used in controlling the safety performance of a transportation system. Because of the very large and complex nature of transportation systems, effecting any changes proceeds very slowly. In addition, changes in the control variables by countermeasures generally have an output response that can only be observed after a rather long period (slowness of accident registration).

Decisionmakers need indicators that detect changes at an early stage in order to anticipate developments in the output of the transportation system. In order to control the safety of the system, they need knowledge about the relation between the changes brought about by possible countermeasures and the effects thereof. However, causal relations between countermeasures and output indicators are too complicated. What is needed is a breakdown of the total process into subprocesses and a theory explaining the effects of attributes of countermeasures on each of these subprocesses.

This paper discusses a structure of subprocesses that facilitates the development of process-indicators that can be linked up with the theories relevant for the subprocesses. These process-indicators and the relevant theories should have sufficient predicting force for the effect of countermeasures.

Introduction

> One accident with one death is a tragedy for those concerned; one accident with ten or more deaths is a disaster; one million accidents a year with 2,000 deaths and 60,000 injured is a statistic.

The transportation system, in its present form and function, is in fact the work of monodisciplinarian scientists and decisionmakers. Town and transportation planners decide which roads should be built and where; traffic experts decide how the roads should be designed; road builders decide how these roads should be constructed and of which material. Vehicle experts decide how vehicles should be designed and function; behavior scientists and legal experts decide how the roads and vehicles should be used. Strictly speaking, everybody operates independently, more or less, without enough knowledge of the others' fields of interest. The road user, limited in his possibilities to perceive, decide and act, has to function in a system in which the coherence of the elements (road, vehicle, traffic and surroundings) often is not taken into consideration. The lack of coherence of the elements of the transportation system not only influences the scope of the aim, the "mobility-production," such as travel miles, travel time, etc., but also brings about undesired "by-products" or adverse effects, such as unsafety.

We often talk about the transportation system and the traffic system, but we do not always realise what the consequences are of applying these system conceptions. Probably the most important characteristic of system thinking is to consider the relevant interactions between the elements or entities in a system.

These interactions are more important than the properties of the element itself.

Since every system is a subsystem of a larger one (the public transport system is a subsystem of the transportation system), choosing the right boundaries of the system model in fact settles the matter. This requires a structural analysis of problems before starting research and before thinking of control possibilities (countermeasures). In making the problem analysis, the following questions can be considered:

- What is the process to be controlled?
- What for and why should it be controlled?
- How should it be controlled?
- Who controls what and where?

In the post-industrial period, in which the western world finds itself, problematic situations and problems are not absolute, but arise from the question: To what extent can the undesired negative "by-products" caused by our individual behavior be accepted? We must realize that society seems to accept the fact that 2,000 people are killed every year in Holland, and 50,000 fatalities occur in the United States, and that all other harm caused by the transportation system is accepted as an inevitable fact. If we resign ourselves to accepting this as an act of God, the safety problem is solved from the point of view of the society.

As the adverse effects of the transportation system, such as unsafety, become more and more unacceptable, we have to begin searching for an answer to the first question: what is the process to be controlled--what is the nature of the phenomenon that is unacceptable?

Transportation (Un)Safety As a Multicausal Chance Phenomenon

Transportation unsafety is a phenomenon that does not occur in every journey. Each journey does, however, involve air pollution, noise and energy consumption. The extent of this depends, among other things, on the modes of transport, the road, the speed, and the distance that is covered.

An accident involving casualties occurs at a given place on a given road, with given vehicles, to given persons, with a given traffic structure and in given weather conditions. However, there are no places where accidents always occur; there are no vehicles that are always involved in accidents; there are no persons who always cause accidents; nor are there any weather conditions that always lead to accidents. Yet, accidents happen; people are killed and injured. Therefore a coinciding of road, vehicle, traffic, and human characteristics and circumstances is apparently needed to cause accidents. The chance of such a critical coinciding of characteristics and circumstances occurring is not the same always or everywhere. Moreover, the consequences of accidents are not always the same but depend, among other things, on the type of collision (for instance car with pedestrian) and the human tolerance of the persons concerned.

If we analyze a traffic safety problem on a statistical level, this implies that we concentrate on averages or central tendencies. The question now arises whether or not this gives the relevant information about the real nature of the problems we want to control. The risks on any trip from A to B are not equally spread over all parts of the trip. We might find that the risk per travel mile of one part is five or ten times higher than another part of the trip. The average risk of the total trip per travel mile has no significance at all for control purposes, especially when the low risk part is rather large. The same accounts for big differences in time, ages, and the like. Therefore, a description of transportation unsafety requires indicators taking into account the nature of the accident phenomenon.

Model of the Accident Process

We live at a time in which social problems are vast, while the resources and means seem to be getting scarcer and scarcer. It is very important, therefore, that effective countermeasures are taken. This means that the decisionmakers need knowledge and information on the effectiveness of the potential countermeasures.

As part of a policy, countermeasures considered effective are applied in an endeavour to attain certain goals. We now come to the second question: what for and why should it be controlled?

The countermeasures and the goals are adjusted to each other by the decisionmakers. This implies, as such, that the decisionmakers employ a theory or a theoretical model of the causal relationship between the changes brought about by the countermeasures and the effects thereof.

The countermeasures and the goals are adjusted to each other by the decisionmakers. This implies, as such, that the decisionmakers employ a theory or a theoretical model of the causal relationship between the changes brought about by the countermeasures and the effects thereof.

In fact, the decisionmakers have to choose the correct control mechanism. This concerns the third question: how should it be controlled? Controlling a complex, mass system such as the transportation system proceeds, in fact, very slowly.

One can compare control of the transportation system with the steering of a fully loaded mammoth tanker. If the wheel of such a vessel is swung right round, the effect (the output) will not become noticeable for some time. There are two reasons for this:

a. the slow response by the tanker and the causal lag the slowness of accident registration);

b. The limitation of human perception abilities in noting slow (slight) changes the limitations of statistical analysis methods for disclosing small changes in the pattern of accidents). The moment the changes in output are observed, it is often too late both on the tanker and in the transportation system to take effective, corrective action.

Masters of giant tankers, therefore, do not respond much to changes in the vessel's course (output variable; accident statistics), but anticipate changes in output by responding to data on input and intermediate processes (input and process indicators), such as position of helm, speed, direction and speed of currents. This is possible because they have sufficient knowledge and comprehension of the relationship between control variables and process variables, and the influence this has on changes in output. They do not wait, therefore, until the moment the output (change in course) manifests itself. Ships' captains have acquired this knowledge from real world experience or simulations in which the relationship between control variables (via process variables) and output variables was examined or simulated under different conditions (speed, current, wind). This form of control does require regular "position-finding" in order to verify and adjust that from "dead reckoning."

In terms of the transportation system, this means that output indicators have to be measured in order to verify the predicted relationship between process indicators and output indicators (increase of knowledge).

In the same way as described above, control of the transportation system can also be focused on changing the input of the system, for instance on changing the need or demand for journeys in general or for specific modes of transport.

Therefore, indicators for describing the effects of countermeasures must link up with the (theories on) the sub-processes within the transportation system which are relevant to road safety. In addition to process indicators and output indicators, input indicators should be measured as well.

In other social problems, such as unemployment, the debate on possible countermeasures largely involves differences in theory or even the lack of theories on subprocesses. These are mainly differences in theories on human behavior in relation to the other system elements.

Transportation unsafety is the result of a complex process in the transportation system. A large number of variables (characteristics of the system elements) with many interactions, produce a complex network of relationships expressed in "system behavior."

In this network of relationships, man as an element in the transportation system has the greatest number of degrees of freedom. His behavior is, therefore, most difficult of all to predict.

Theories on the overall process in the transportation system are therefore dangerous and misleading. Theories only have predictive force if all relevant subprocesses are distinguished. In other words, in order to be able to predict the effects of countermeasures, those subprocesses must be distinguished within the process as a whole. Countermeasures can have an opposite effect on the distinguished subprocesses.

In Figure 1 the accident process is shown schematically: starting in the social system from a certain activity, for example, paying a visit somewhere, one will travel with a certain vehicle via a certain route and according to a certain travel scheme (transportation system). One gets involved in traffic situations that effect a certain traffic behavior and "provoke" this behavior to a greater extent. For example, a road with wide lanes will provoke high driving speeds, even in a residential area. Whether a critical coincidence of circumstances arises, strongly depends on the "existence" of certain conditions and their predictability. But, one's own traffic behavior also plays a part in the approach to those circumstances. For example, a critical coincidence arises when a road user approaches an intersection at high speed, with cross-traffic approaching at the same time. If anticipating is possible, because the road user recognizes this critical coincidence in time, a normal braking maneuver can be carried out. If braking in time is not possible, an emergency maneuver is needed. This not only demands ability of reaction and skill of the road user, but also a sufficient friction coefficient between the road surface and the vehicle tires, room for pulling out and adapted steering, and sufficient braking characteristics of the vehicle.

If the emergency maneuver is successful, an incident (or conflict) arises. The consequences are: getting frightened and, depending on the presence of other road users or vehicles, a chain disturbance, that is to say, the accident vehicle causes a new critical situation for approaching vehicles. If the emergency maneuver fails, an accident arises. The victims of the accident can be not only the considered road user himself, but also other road users.

On the one hand, the consequences (in terms of injury) depend on the forces that affect people during the collision and on human tolerance. Human tolerance is not the same for everybody. Young people have a far greater human tolerance than the aged. High death figures of aged people (in traffic and in the private sphere) can be explained better by low human tolerance than by restricted perceptive capacity or reaction ability.[2] Such restrictions are mostly compensated by "careful" behavior.

At last there is the recovering phase. It is a pity that not all the survivors will recover fully. Too little attention is paid to this aspect. Each year new permanently disabled persons have to be added as statistics to the data of the previous years.

In Figure 1 the feed-backs between the phases are not taken into consideration. There are also more feed-forwards possible in the model. In the example of traffic lights some of the feed-backs are given.

The impression may be created that it is a simple matter to supply sets of process indicators and output indicators suitable for general use. Unfortunately it is more complicated than this. Indicators must be a criterion belonging to a stated problem. We rarely study the transportation system as a whole, but subsystems instead. Even so, we tend to focus on aspects of subsystems, such as traffic hazards at intersections, the unsafety of pedestrians, cyclists, etc. For correct use of the indicators, the choice of the (sub)system boundaries is very important.

This may be illustrated by the following example. (See Figure 2). A road authority has in its road network an intersection where a comparatively large number of accidents occur, causing may casualties (problem related to output indicators). Actually, the observation of the critical coincidence of circumstances by the road users is defective. This is apparent from faulty or even non-anticipating traffic behavior that people do not always decelerate sufficiently and sometimes not at all (problem related to process indicators). The authority thinks it can solve the problem by installing traffic lights (countermeasures). What does such a countermeasure bring about on the accident process? See Figure 1 again and also Figure 3.

Installing traffic lights at one intersection will not deter road users from making as many journeys, nor will they change over to a different mode of transport. What they may do is to select a different route to avoid traffic lights. We must therefore know the input indicators for the intersection, for instance, the number of approaching vehicles. But, we must look also beyond the intersection for other roads (extension of system boundaries) where the input indicators increase (more traffic on the roads). The effect of installing traffic lights in the phase of route selection can be fewer approaching vehicles. The effect of fewer approaching (and hence passing) vehicles in the phase of traffic behavior "provoked" in advance may be higher speeds. The effect of higher speeds in advance may be poorer observation of critical coincidences so that these are anticipated too late or not at all. An emergency maneuver (emergency stopping) may then still prevent a collision, provided the road surface there has sufficient skidding resistance.

There are a number of hypotheses which are important for determining indicators from this example.

- Fewer approaching vehicles, when traffic lights are inflexibly regulated, may even result in more people driving through the red lights, often with very serious consequences. All phases of the accident process then have a negative rating.

- Higher speeds in advance without anticipatory behavior influence the success or failure of the emergency maneuver.

- Traffic lights may bring about a different kind of critical coincidence of circumstances, not because of the intersecting traffic but because of the queue at the traffic light that is being approached. The location of the critical coincidence "moves" downwards in Figure 3 with regard to Figure 2. Failing anticipation and the emergency maneuver (including evasive action) will cause another type of collision: head-to-tail instead of flank impacts.

- The effects of head-to-tail impacts are often less serious than those of flank collisions (crumple zone).

In this example of installing traffic lights at an intersection, the site of the critical coincidence of circumstances is determined by the intersection. However, there are also critical coincidences without a fixed location, such as at the end of a (variable) queue, with overtaking maneuvers in a traffic flow, in a traffic flow with short-following headways and so on.

From the example above we learn that theory, hypothesis, and process indicators and the general accident model go hand in hand.

How are these research elements related to each other? See Figure 4. On the operational level we can make statistical models of the indicators. We must realise that on the operational level there are no causal relations, so we need the transformation to the theoretical level of the different process-phases. From these phases we can choose the right variables and process indicators on the operational level. The generalised, structural model gives the framework for the different process-phases.

For controlling a system and thus for choosing the right countermeasures we need knowledge on the theoretical level related to the general framework.

If we want to know the effects of countermeasures, we need to develop the following kinds of indicators in the above example:

- Input indicators, for instance, approaching vehicles (per unit of time);

- Process indicators for "provoked" traffic behavior in advance (for instance, speed), for observing critical coincidence of circumstances (for instance, mental activation level), for "anticipatory" traffic behavior (for instance, deceleration), for emergency maneuvering (for instance, deceleration and/or change of course), and for crash behavior (for instance, impact decelerations);

- Output indicators (for instance, type of accident, number of vehicles in accidents, number of persons in accidents, number of casualties and number of permanently disabled).

On the question of what are the best performance indicators to describe the safety aspect of the transportation system, there is no general answer. Indicators are mostly used to make comparisons between countries, periods (before and after countermeasures), different categories of roads or road users, age groups, traffic situations, etc. The choice of the relevant sets of indicators is dependent on the problem setting and the proper questions raised from the problem analysis.

Example of a Set of Output Indicators

Output indicators for transportation unsafety mainly express a kind of risk, that is to say, a chance of an accident or a chance to be killed per inhabitant, per persons-kilometers of travel, etc. Here we have to consider carefully the fact that the numerator and the denominator are in all cases compatible. An output, such as $\frac{\text{number of casualties}}{\text{number of vehicle kms}}$, is not unambiguous. One vehicle may have more than one occupant in an accident (accident persons) and one accident may involve several vehicles (accident vehicles).

An indicator, such as $\frac{\text{fatal accidents}}{\text{number of vehicles kms}}$, can also give a badly distorted picture. For instance, a bus has a comparatively large number of fatal accidents per vehicle kilometer (in The Netherlands about 4 times higher than a private car), the victims mostly being the other parties, especially pedestrians. This does not mean, however, that replacing buses with cars would make the roads safer. The high occupancy of buses (an average of twenty persons in The Netherlands) and the low occupancy of cars makes one bus equivalent to about ten cars. Ten cars together will cause more casualties than one bus. (This does not pertain to empty buses or buses with tow occupancy.)

Sets of indicators are mostly needed in order to describe the phenomenon. In Figure 5 an example is shown of such a set of indicators. The indicator $\frac{\text{number of casualties}}{\text{number of persons involved}}$ gives the link from the transportation system to the social system and facilitates a comparison with other threats in society. Every indicator has a certain significance, that is it links up with certain theories and models. The indicator for accident occupancy, for instance, $\frac{\text{number of persons in accidents}}{\text{number of vehicles in accidents}}$ links up with a theory claiming that the number of occupants influences the driver's possibilities of perception and may even influence the "provoked" traffic behavior in advance and the "anticipatory" behavior (in an adverse sense). The indicator for severity of an accident, for instance, $\frac{\text{number of casualties}}{\text{number of persons in accident}}$, links up with theories of human tolerance. For example, if old people are involved in an accident, this indicator will turn out very unfavorable (low human tolerance).

The set of indicators shown above provides the possibility of obtaining a clear interpretation of the unsafety of the whole transportation system on the basis of various problems and from various approaches, and at the same time provides a framework and an incentive for the planned collection of data. Specifications of these indicators are necessary, and we have to break down the transportation system into subsystems, such as the various modes of transport, different age groups, various smaller or bigger areas (localities, regions, etc.), and the various types of confrontation, such as car/bicycle, bus/pedestrian, and so on. The same formula can be used for this purpose.

Subjective Risk and Feelings of Danger

Research in The Netherlands indicates that, especially in residential areas, many decisions regarding road safety are taken on the basis of the residents' feelings of danger and subjective risk. We must realize that traffic in residential areas is different from that in specific traffic areas. In residential areas in The Netherlands, pedestrians account for about 40% of all journeys, while a high percentage of car journeys in such an area is home-based. This means that the same persons alternate between being pedestrians and motorists. In the confrontation with motorized traffic the pedestrian is the most vulnerable, and in this role he also experiences the fear of accidents and feelings of danger. By voice in neighborhood councils, he can put this experience before the local authority and use it as a means to press for countermeasures. They hardly realize that the countermeasures are then in fact adopted for them in their role of motorists.

Many voices are being heard asking for measures and indicators to be developed for subjective risk (that is, fear for accidents and feelings of danger). There are also appeals to base road safety policy largely on subjective risk. But, before we can answer the questions about indicators, we have to start again with the first question: "What is the process to be controlled?" Only if we have enough insight and theories about this phenomenon and about the way it works in the individual and collective decision process, can we start to develop indicators for subjective risk.

When we analyse this phenomenon of subjective risk or feelings of danger, we have to pay attention to the diversity in the way it appears. Situations regarded as subjectively risky are often objectively very safe. This is not surprising, because feelings of danger often have a favorable effect on the perception of critical coincidences and on "anticipatory" traffic behavior. In addition, feelings of danger depend upon the role one plays in the transportation system (pedestrian or motorist). I think it is better to give the decisionmakers better tools to resist pressure from neighborhood residents and to direct their interests in a different direction if necessary.

Process indicators linked up with theories that have prediction force for the output could be such a tool. By using these indicators, decisionmakers could base their policy on what they know and not (only on public acceptance of their measures.

Conclusions

- System safety is primarily a complex control problem.
- Knowledge must be structured in such a way that the decisionmakers can control transportation system safety. Necessary conditions are: insight into and theories about relations between countermeasures and the effects thereof and process indicators with predictive force with respect to output.
- Output indicators must be measured continuously to determine if the right course is chosen and if the corrective actions are effective.

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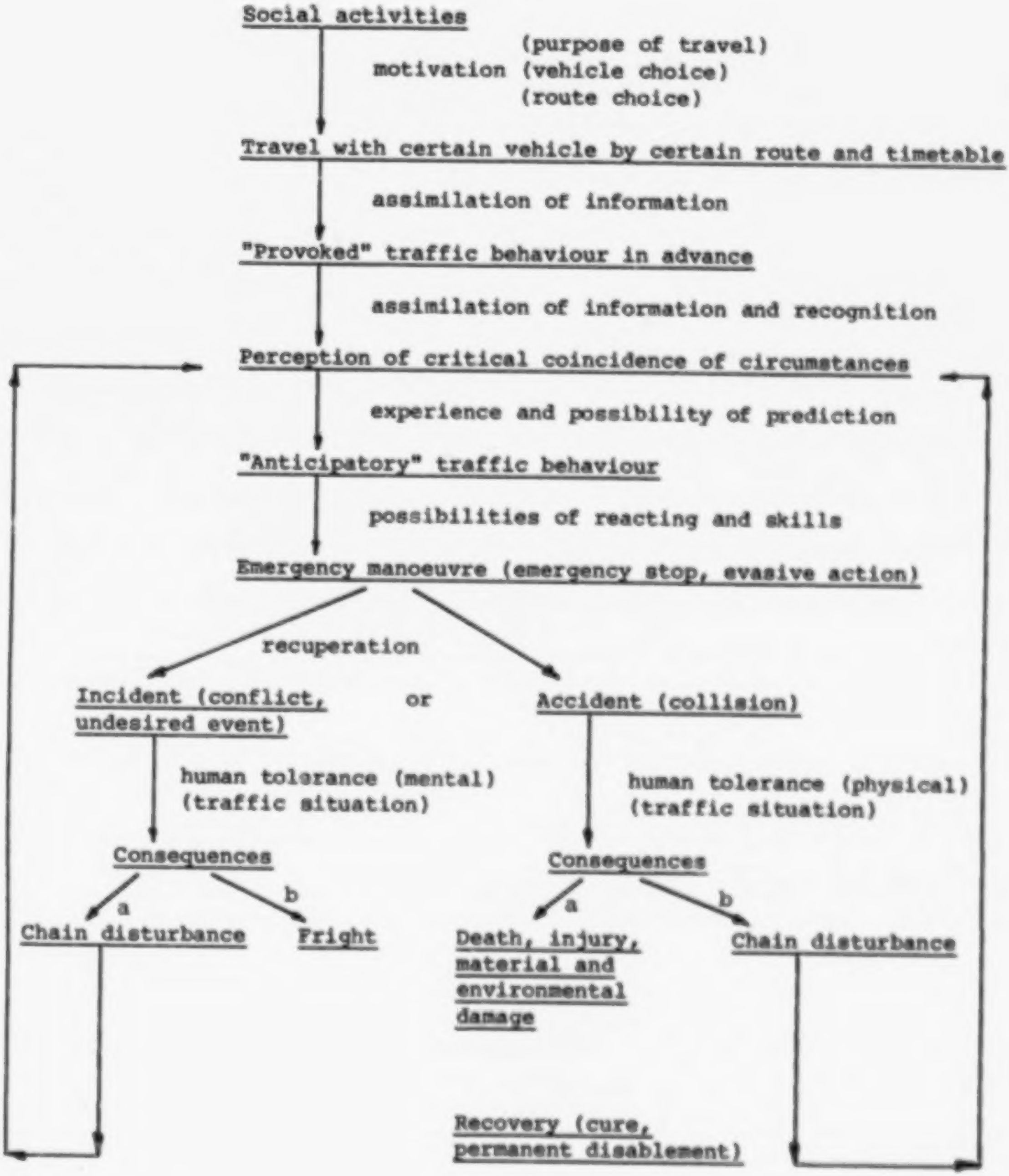
Picture 1. MODEL OF THE ACCIDENT PROCESS


Social activities
motivation
(purpose of travel)
(vehicle choice)
(route choice)
Travel with certain vehicle by certain route and timetable
assimilation of information
"Provoked" traffic behaviour in advance
assimilation of information and recognition
Perception of critical coincidence of circumstances
experience and possibility of prediction
"Anticipatory" traffic behaviour
possibilities of reacting and skills
Emergency manoeuvre (emergency stop, evasive action)
recuperation
Incident (conflict, undesired event)
or
Accident (collision)
human tolerance (mental)
(traffic situation)
human tolerance (physical)
(traffic situation)
Consequences
a
b
Chain disturbance
Fright
Consequences
a
b
Death, injury, material and environmental damage
Chain disturbance
Recovery (cure, permanent disablement)

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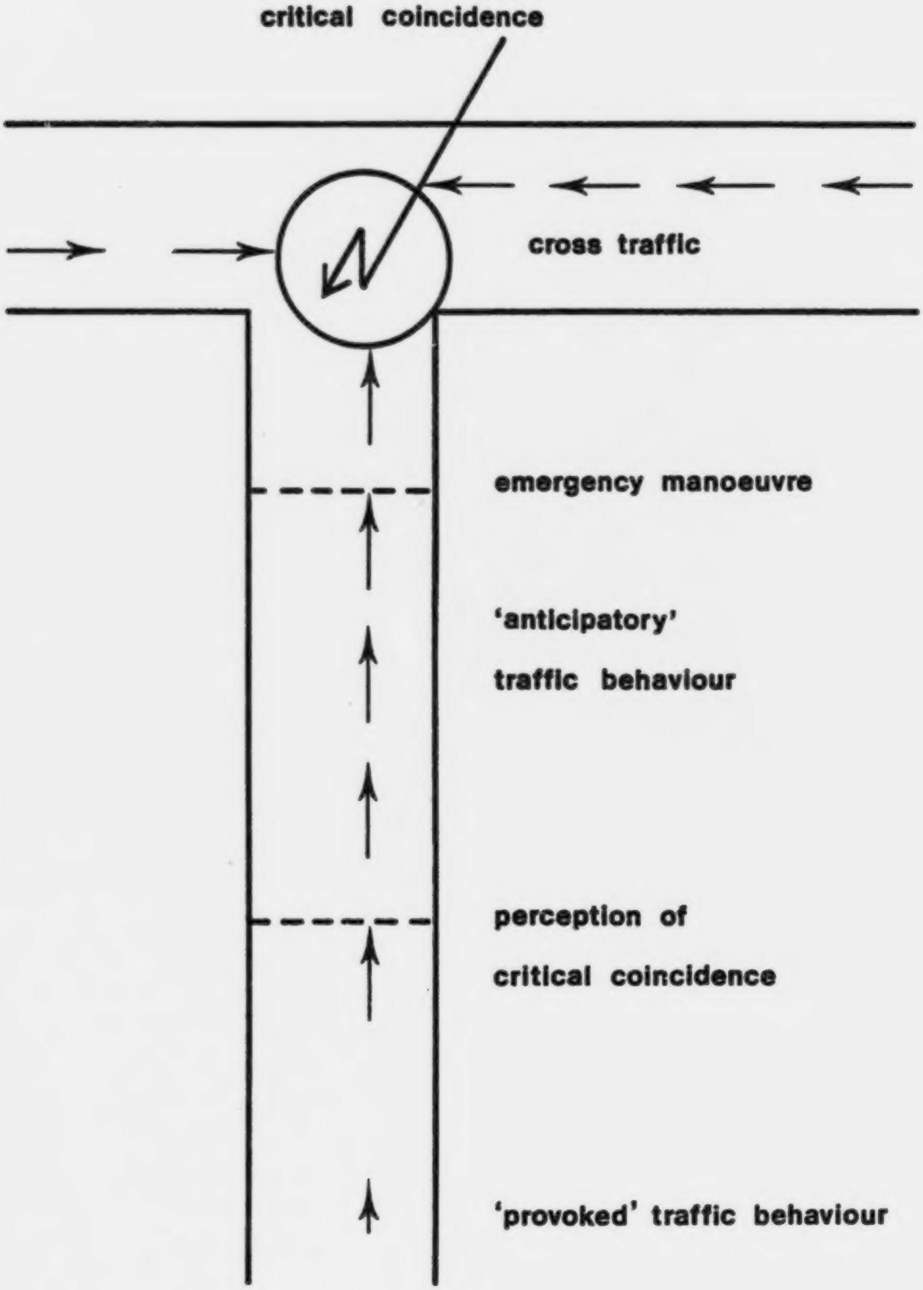
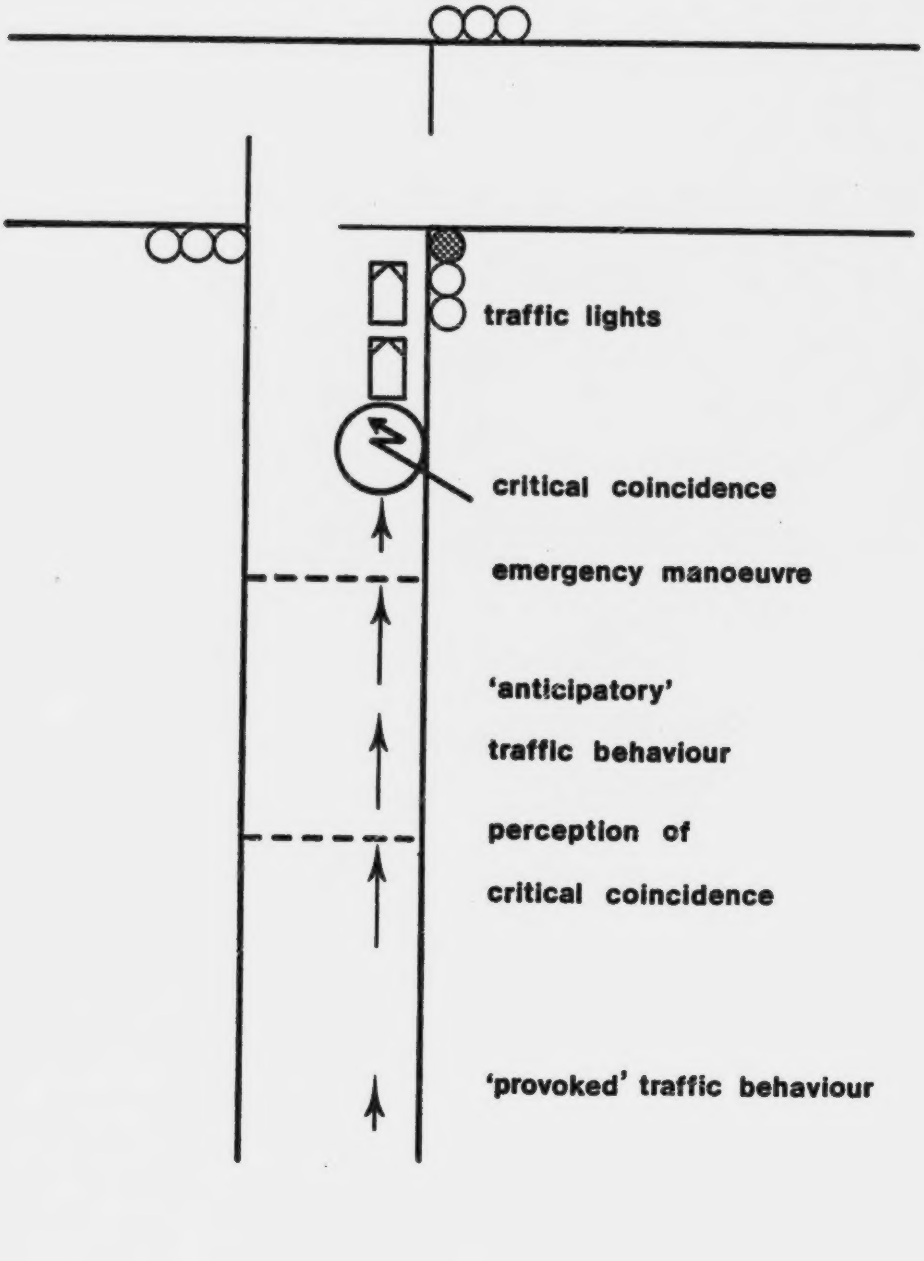
Picture 2.

ACCIDENT PROCESS BEFORE INSTALLING TRAFFIC LIGHTS


critical coincidence
cross traffic
emergency manoeuvre
'anticipatory'
traffic behaviour
perception of
critical coincidence
'provoked' traffic behaviour

Picture 3.

ACCIDENT PROCESS AFTER INSTALLING TRAFFIC LIGHTS


traffic lights
critical coincidence
emergency manoeuvre
'anticipatory'
traffic behaviour
perception of
critical coincidence
'provoked' traffic behaviour

BEST DOCUMENT AVAILABLE

Picture 4.

RELATION BETWEEN RESEARCH ELEMENT OF DIFFERENT LEVELS

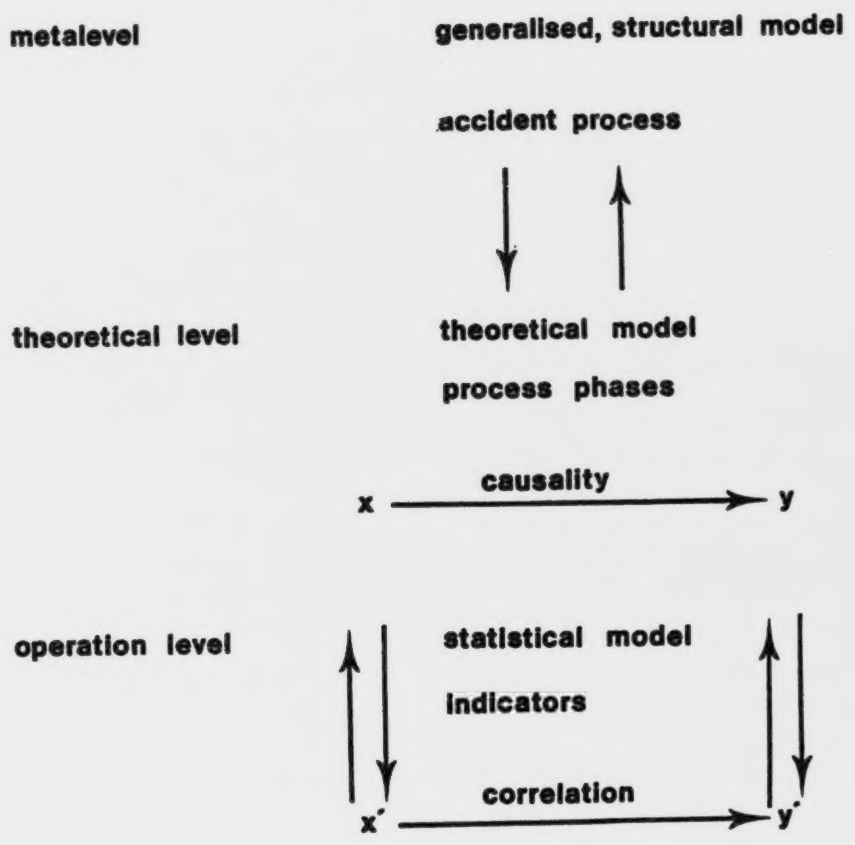

metalevel
generalised, structural model
accident process
theoretical level
theoretical model
process phases
x
causality
y
operation level
statistical model
indicators
x´
correlation
y´

Figure 5. EXAMPLES OF A SET OF OUTPUT INDICATORS

General set (tautology):

$$\underset{\text{(total unsafety)}}{\frac{\text{number of casualties*}}{\text{number of persons involved}}} = \underset{\text{(mobility)}}{\frac{\text{number of traveller kms}}{\text{number of persons involved}}} \times \underset{\text{(occupancy)}}{\frac{\text{number of vehicle kms}}{\text{number of traveller kms}}} \times \underset{\text{(accident complexity)}}{\frac{\text{number of accident vehicles}}{\text{number of vehicle kms}}} \times$$

$$\times \underset{\text{(accident occupancy)}}{\frac{\text{number of accident persons}}{\text{number of accident vehicles}}} \times \underset{\text{(accident severity)}}{\frac{\text{number of casualties*}}{\text{number of accident persons}}}$$

Specific set for bicycle traffic:

$$\frac{\text{number of bicycle casualties}}{\text{number of bicyclists}} = \frac{\text{number of traveller kms on bicycle}}{\text{number of bicyclists}} \times \frac{\text{number of bicycle kms}}{\text{number of traveller kms on bicycle}} \times$$

$$\times \frac{\text{number of accident bicycles}}{\text{number of bicycle kms}} \times \frac{\text{number of accident bicyclists}}{\text{number of accident bicycles}} \times \frac{\text{number of bicycle casualties}}{\text{number of accident bicyclist}}$$

Other specific sets are possible for other means of transport, various age groups, regions, locations, confrontations.

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*Casualties: killed and injured; only killed or only injured

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STATE HIGHWAY SAFETY PROGRAMS IN THE UNITED STATES: STATE OF THE ART

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Abstract

Progress in the area of highway safety in the United States is losing its impetus, and this is occurring at a time when deaths due to highway accidents are likely to worsen as we switch to smaller cars to save gasoline.

This paper attempts to analyze what factors have effected an increase in U.S. highway deaths and what might be done to bring about a decrease in the future. Specifically, this paper focuses on the societal costs of highway accidents, and provides a summary of the current status of the State and Community Highway Safety Program (402 Grants) in the United States.

Introduction

The prospects for safe travel on United States highways are taking a turn for the worse. The increased death rate due to the influx of small cars seems about to be made worse by a retreat from support of other aspects of highway safety. In this presentation, I would like to try to analyze what went wrong, and also what might yet be done to counter the surge of highway deaths that will occur in the next few years.

Cost of Highway Accidents

A legitimate question in examining any problem facing society is whether the problem itself is important enough that society is really interested in controlling it and what resources are available to control the problem relative to its size and severity.

In the United States there is a familiar litany of numbers that characterize society's losses from automobile accidents. The United States suffers more than 50,000 deaths and about 4,000,000 injuries per year and approximately 35-45 billion dollars in yearly accident costs, depending on which estimate is used.

Such large numbers abound in our country that we become almost inured to the significance of numbers that are merely large. Perhaps a more compelling way to characterize the size of our motor vehicle accident problem is to compare it to other major threats to the health of U.S. citizens. Two well-recognized threats to our health are cardiovascular diseases and cancer. We are familiar with the enormous annual dollar costs that result from these two diseases. What is less well understood, however, is that the annual cost of motor vehicle accidents ranks right along with these two terrible diseases.

Each year, motor vehicle accidents result in greater health costs than cardiovascular diseases and are a close second to cancer.[1] As a matter of fact, the costs of motor vehicle accidents is a full 60% as much as the vast and staggering cost of cancer.

Thus, it is correct to characterize automobile accidents as the second greatest threat to the health of this nation, and they are close in magnitude to the leading threat. As is well known, cancer tends to strike older people, whereas motor vehicle accidents tend to involve younger people. Motor vehicle accidents are the leading cause of death among the younger half of the people of this nation.

Thus, there is a great similarity between cancer, cardiovascular diseases, and motor vehicle accidents in terms of costs to American society. However, when it comes to societal resources devoted to trying to find ways of offsetting these problems, the similarity ends abruptly. One might think that if motor vehicle accidents constitute 60% of the cost of cancer, perhaps the resources to fight the problem would be 60% as much. Instead, we find that the cancer-fighting resources are about 100-fold greater than those devoted to motor vehicle crashes.[2]

I realize that with the U.S. economy being as advertised, it is inappropriate to talk about increased funding for anything other than military power. But at least we should be realistic about our expectations for highway safety programs since Federal funding resources are trivial. Consider what progress might be expected in the field of cancer if its research budget were cut 100-fold.

Ironically, the worsening of the accident situation will increase cost pressures in some of the very areas the current administration wishes to cut; that is, welfare, social security, medical costs, etc. Yet, to a substantial extent, these costs are generated because of the dependencies and disabilities created by disablement or death from highway crashes. For example, auto accidents constitute the leading cause of new epilepsy cases[3] and are the leading source of paraplegia and quadriplegia.[4]

Any reasonable interpretation of the situation shows that the cost to society of motor vehicle accidents is exorbitant and that the resources available to find ways to offset this cost are trivial in comparison to that for other health problems.

The Situation is Much Improved

Despite the fact that progress is now threatened, large highway safety improvements have been made. Perhaps the most dramatic single example of the safety improvements of the last 15 years (partly due to Federally-sponsored research and partly due to auto industry research) is improvements in car occupant crash protection. Analysis of North Carolina data has shown that there has been a significant reduction in the probability of occupant death or serious injury in more recent model cars than was true in cars a few years earlier.[5] This improvement is of the order of 40-50%, an improvement sufficiently profound to bring down the whole national death rate, at least in the era prior to the recent onset of small cars. There can be no doubt that standard equipment on cars sold in the United States, like energy-absorbing steering wheels, improved windshield glass, head restraints, padding, and various structural changes, has materially improved the situation.

State Highway Safety Program "Failure"

Despite progress in vehicle safety, today's state of the art is rather grim, with State Highway Safety Programs deemed by some to be essentially a failure. For example, while the General Accounting Office (GAO) report[6] refers to State Highway Safety Programs (funded under Section 402 of the U.S. Highway Safety Act) as a "limited success," in reading the text, one sees that the faint praise on the cover page precedes an indictment within. This report, prepared by an investigative arm of the U.S. Congress, deals with the program of Federal highway safety grants to States. These Federal grants are small, relative to the highway safety expenditures of states (about 2-3%), but are designed to support innovative programs which, once developed with the grant funds, can be implemented on a larger scale by the States using their own funds.

I argue very strongly that this program has indeed enjoyed "limited success," and that is as much or more than can be expected for the trivial level of Federal grant funds made to States. This grant program has had limited success, but there also have been shortcomings and "failures."

Allow me first to talk about some of the shortcomings which I fear opened the way to the severe cuts in the Federal grant program of the current administration. The status of too many State driver safety programs was really not very good 15 years ago when the Federal role was established and began to expand. There had been relatively little innovation over the years. In the absence of firm quantitative information on program effectiveness, myths and folklore abounded as to the nature of accidents and the effectiveness of various countermeasures.[7] The degree of professionalization within the highway safety movement was not very great, and the number of highway safety professionals with the training necessary for good effectiveness evaluations was very limited. State highway safety programs were by and large unevaluated and, of those evaluated, too many seemed to show up as being ineffective.

I am sorry to say that 15 years later the situation is not nearly as improved as one would reasonably hope. There are still very few States equipped to implement and evaluate truly innovative programs. For example, the National Safety Council is putting together a symposium on evaluation, a most laudable and much needed activity. However, in preparing for this meeting only a very limited number of good evaluations could be found on record, and these came from only a handful of States.

Many times States introduce what they apparently consider to be "new" programs when in fact those programs have been tried (and often have failed) in other States. Rarely do the States appear to know which programs have been introduced elsewhere and whether or not they met with success. Equally rare is the process of building evaluation procedures into new programs to determine whether the program is accomplishing its goals. Whereas one might have understood this state of affairs 15 years ago, it is more difficult to accept today how this situation persists.

The outlook 15 years ago was good. The National Highway Traffic Safety Administration (NHTSA) started out with a commendable requirement for evaluation, set forth explicitly in most of the Highway Safety Standards they issued and under which project grants were financed. Also, over the years, NHTSA (and others) conducted various workshops on evaluation methods, and under contract they had "how to do it" evaluation manuals prepared. Yet very little change came about in the program evaluation procedures used by States. The reason is that very few States took it on themselves to incorporate these procedures, and NHTSA did not demand that they do so. The political reality, however, is that NHTSA has limited financial and statutory clout to force the States to act.

The program is approaching its fifteenth year, and to its credit NHTSA is seriously pursuing the issue of impact evaluation. As a companion effort, NHTSA needs to disseminate to State officials appropriate findings from research and State grant programs. An endless complaint from the States over the years has been that NHTSA has not digested and disseminated the success stories (failure stories are equally as valuable) to States in such a manner that they could be used. NHTSA says that lately it has increased this emphasis.

The General Accounting Office Report

The points I made above are in considerable agreement with the GAO report. However, I disagree with other aspects of the GAO report, and I think that to a considerable extent, GAO gave the Federal grant program a less than desirable appraisal. First, as bad as it is, the evaluation situation is better than GAO indicated. There are some States which have given considerable attention to evaluation over the years. (I am happy to say my home State of North Carolina is one of them). The State of California has pioneered in this area for more than two decades. None of this was reflected in the report.

The GAO report also makes the very serious mistake of implying that the low cost level grants to States that Congress has funded can in fact make a discernable impact on the accident problem. The GAO report refers to the large number of projects of $20,000 or more and cites the absence of evaluation showing bottom-line success. It should be obvious, upon considering the nature of the accident problem, that a zero result is exactly what one should expect for almost any $20,000 project. Small projects of this type might be cumulatively good, but it is difficult to demonstrate the benefits. The size of the accident problem is simply too big to expect measurable benefits with this kind of trivial funding.

Thus, the mistake which comes out of Congress is expecting the State grant funds, in themselves, to routinely show bottom-line results. It would be more realistic to hope that these funds could be used as triggering funds to make possible innovations and improvements which would in turn be implemented through the much larger state-wide operational budgets. There are examples of how this has been done in North Carolina in the citation I have provided.

Even within the better funding limitation, there have been some real successes. In North Carolina alone, programs have been evaluated and shown to be successful.[8] Driver license tests have been improved, and pilot efforts have been tried; some were successful, some were not. Even a pilot effort which fails is a savings because the costs of full-scale implementation are avoided. Regrettably, the GAO report did not show the successes that have been achieved.

What About the Future?

The United States needs a Federal grant program for the States. We need it to be funded at a level which can at least provide some triggering funds by which innovative efforts can be tried out so as to guide the larger level of State funding.

We need a rigid requirement for evaluation of impact programs. NHTSA should insist on this, and the States need to get busy and equip themselves to do this.

Implied in a requirement for evaluation is that the States have access to the staff capability for advanced planning with respect to new programs. For example, it really does not seem so radical to expect that a State, before it embarks on a program, will at least do a background review of previous attempts at similar efforts carried out elsewhere, and yet this is rarely done. (I specifically refer here to driver improvement clinics, drunk driver schools, and the like.)

In administering their highway safety programs, States should perform at least three tasks:

1. Study what has been carried out before and be familiar with the successes and the failures;

2. If a State plans to go ahead with a program which has failed before, be prepared to specify what is different about the approach and that it believes the new approach will succeed;

3. For significant impact programs, build in an evaluation, write up the results, and disseminate these reports to NHTSA and the other States.

The above is nothing more than routine, good common sense--routine in good business practice, and routine in good management. But it has been routinely omitted in the highway safety field. Worst of all, in the absence of objective program monitoring, as indicated above, the highway safety mythology and folklore goes on unabated. With few exceptions, the States are not doing this evaluation, and NHTSA has not insisted on it except for its very recent efforts. I hope NHTSA succeeds in this effort, and I hope the States will not resist. The technical requirements to carry out programs on the basis outlined above are not that difficult to achieve. The know-how to accomplish this is available.

I will end this assessment of the bleak present situation with an equally sober look at the future. The highway safety situation in the United States is going to get worse in the next few years. The energy situation has dictated the massive influx of small cars we see now. We will see the number of deaths in the United States begin to rise sharply with the well-documented[9] higher probability of death and serious injury when these cars crash. In only a year or two, the public will begin looking for someone to blame for the tragic increase in highway deaths.

My formula to try to offset this situation in the next few years is, first, to encourage the Reagan Administration to go ahead with the passive restraint occupant protection standard. The only countermeasure powerful enough to offset inevitable increase in deaths due to small cars is to achieve a change from today's essentially unrestrained population to an essentially restrained population in the future.

Those of you who know me well will recall that I have not been known, in past years, as a leading air bag fan. Therefore, I want to tell you why I am saying we should go ahead with automatic restraints. Although a few years ago I was not excited about the immediate adoption of air bags, I did endorse the idea of automatic protective systems. In fact, one of the reasons I was unenthusiastic about the air bag was that it is not a fully automatic system--the lap belt must be buckled to get full protection. Since that time, the auto industry has developed alternative systems, including automatic seat belts, in addition to the air bag with lap belt. Also, there has been time for additional testing and development. Thus, the situation is better than it was a few years ago. Also, the urgency of the situation is now markedly greater. Even though the urgency of passenger restraint has been great all along, it is much greater today because of the small cars. Thus, I think the administration should go ahead with the passive-restraint occupant-protection standard.

Second, I think the administration must go forward with at least enough of a State grant program to give some hope that at long last the highway safety establishment will abandon the folklore of this field and try more rapidly to develop quantifiable, effective programs. To help the States do this, the NHTSA research and development program needs to help with conducting training, disseminating research, and developing ways for the States to move ahead.

Unless State highway safety programming improves and unless we do something about occupant restraint, the United States death rate will rise. (The only other thing that might keep our death rate down would be a sharp reduction in gasoline supplies, which is undesirable.) With economic recovery and adequate gasoline supplies, deaths are going to rise. The question is whether we are going to let the Federal safety movement in the United States evaporate just as we are threatened with large increases in the death rate or try to retain a viable Federal program to offset this trend. Right now, it looks like the United States Government has opted for reduced highway safety. I think the outlook is grim for the next several years.

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INDIVIDUAL AND GOVERNMENTAL CHOICES BETWEEN FREEDOM AND SAFETY

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Abstract

The paper is based on the research work done by the author and sponsored by the Academy of Finland and Liikenneturva (National Traffic Safety Organisation) in the years 1978-1980. It included field surveys in which the behaviour of pedestrians and drivers was observed in six Scandinavian cities.

Safety alone as a performance concept is rather meaningless. It must be related to how it affects freedom of movement. The level of protection afforded by a transportation system is the result of choices between freedom and safety made by governmental authorities. Traffic behaviour is a result of choices made by individual pedestrians and drivers. Governmental choices can be seen in engineering features, traffic control, and traffic law. Large legal and police organizations are needed to get people to accept the governmental choices.

In the survey six conditions were selected for study, each representing common traffic situations in urban areas. Engineering features and traffic laws were analyzed and the governmental choices were determined. By observing the behaviour of pedestrians and drivers in these situations, the individual choices between freedom and safety were determined. On the basis of these observations, general principles were formulated of how individuals make their choices within the framework formed by the governmental choices. A discussion of the implications these principles have on governmental policy is also included.

Introduction

Traffic safety can be seen as a function of freedom of movement. For example, safety on a highway with a 55 mile per hour speed limit is much better than on a highway without a speed limit. By reducing speed, or in other words reducing freedom of movement, government increases safety. This simple example shows that there is an interconnection between safety and freedom.

How one understands this relationship can affect governmental policy decisions. The effect of speed limits is a well documented fact;[1] however, a lot of people do not obey speed limits. The reason is quite clear; they want to drive at higher speeds--in other words, have greater freedom of movement than government is allowing. Depending on the circumstances, when exceeding the speed limit a driver may or may not decrease his safety. We can see that there is a conflict between governmental and individual choices. When the choices do not coincide, large legal and police organizations are needed to gain the people's acceptance of the governmental choices.

Presented in this paper are observations of the conflict between urban traffic safety and freedom of movement. In urban street traffic the choices between safety and freedom are more complex than on highways. In addition to the conflict between governmental and individual choices, there are conflicts between various individuals, for example, between pedestrians and motorists, as well as among the motorists themselves.

The choices made at the governmental level and at the individual level are determined by completely different rationales. Governmental rationale is mainly determined by the consideration of engineering factors and traffic laws. The choices made at the individual level are determined on the basis of observed behaviour.

The data used in the next chapter is based mainly on surveys conducted by the author in six Scandinavian cities from 1978 to 1980. The objective of the surveys was to determine who voluntarily yielded and who strictly followed the traffic laws under the following six traffic conditions:

1. Pedestrians crossing a street along a signalized crosswalk
2. Pedestrians crossing a street along an unsignalized crosswalk
3. Pedestrians crossing a street outside/without crosswalks
4. Cars at a signalized intersection
5. Cars at an unsignalized intersection
6. Cars at an intersection with yield signs

All crosswalks in the survey were marked with longitudinal lines and also had pedestrian crossing signs. In all crosswalks there were separate indications for vehicular traffic and pedestrians. The pedestrian signals were indicated by a steadily illuminated green walking-man or red standing-man light unit. No flashing phases were used. The traffic control signals were indicated by steady green, yellow, red, and red with yellow phase light units.

The surveys were conducted in the Scandinavian capitals: Helsinki (480,000 inhabitants), Stockholm (700,000 inhabitants), Oslo (470,000 inhabitants), and Copenhagen (700,000 inhabitants), and in the Finnish towns of Lappeenranta (53,000 inhabitants), and Savonlinna (28,000 inhabitants).

Pedestrians Crossing a Street Along a Signalized Crosswalk

Governmental and individual choices between safety and freedom of movement are discussed as two concerns for this traffic situation: pedestrians facing the red pedestrian signal indication and the conflict between pedestrians and turning cars.

In the first concern, the governmental choice is to increase pedestrian safety by reducing pedestrian freedom of movement. Pedestrians are not allowed to enter the crosswalk against the red indication. In Norway, governmental choice prefers more pedestrian freedom of movement, and therefore allows them to cross against a red light, but only if the crossing may be made safely and without inconvenience for vehicular traffic. In the second case, that of conflict between pedestrians and turning cars, the governmental choice is to reduce drivers' freedom of movement where the driver is required to yield to the pedestrian. The aim, thereby, is to increase pedestrian safety and freedom of movement.

According to my observations, 7% of pedestrians started to cross the roadway against the red indication in Helsinki. Percentages in the other cities were: Stockholm 25%, Oslo 28%, and Copenhagen 11%. According to Sakshaug and Sten, 22% of observed pedestrians did cross against the red indication in Norway.[2] However, only 0.7% of the crossings had conflicts with vehicular traffic and in this way were against the Norwegian law. When considering that about 50% of the pedestrians arrived at the street corner during the green phase and did not have any possibilities to cross against the red indication, we can conclude that of the pedestrians arriving during the red phase, 15% in Helsinki and almost 50% in Stockholm and Oslo, started to cross the roadway against the red indication.

In observing conflicts between pedestrians and turning cars, I noticed that in 39% of the conflicts a pedestrian had stopped and yielded the right-of-way to a car, and in 61% of the conflicts a car had stopped and given the right-of-way to a pedestrian.

The survey figures show that in many cases pedestrians, when facing a red indication, chose to increase their freedom of movement from that stated in traffic laws and crossed against the red signal. By doing so, depending on the circumstances, they may or may not have decreased their safety.

When observing the conflict between pedestrians and turning cars, it can be seen, by the pedestrians yielding to vehicles, that pedestrians are decreasing and car drivers are increasing their freedom of movement from that required by the government. One obvious reason is that pedestrians are not willing to risk their safety with approaching cars. Also the time needed for a car passing by is rather short and, therefore, pedestrians do not feel their freedom of movement is reduced much.

Pedestrians Crossing a Street Along an Unsignalized Crosswalk

According to Finnish traffic law, a motorist approaching a crosswalk has to adjust his speed so that he does not endanger the pedestrian who is in, or is entering, the crosswalk. The law states that a pedestrian entering an unsignalized crosswalk must take into consideration the distance and the speed of approaching cars. The laws in other Scandinavian countries are similar.

The governmental choice in this case has been to decrease both drivers' and pedestrians' freedom of movement, thereby increasing pedestrian safety.

In observing conflicts between pedestrians and approaching cars, I noticed that in 94% of the conflicts in Helsinki a pedestrian had stopped and yielded the right-of-way to a car. In Stockholm it was 87%, in Copenhagen 85%, in Lappeenranta 71%, and in Savonlinna 39%. Only the conflicts where a car or a pedestrian had stopped were observed. In this case it is difficult to compare governmental and individual choices because the governmental choice is not quantitative; that is, the government has not decided who may cross a crosswalk first, a car or a pedestrian. But, again the observed behavior shows that pedestrians are not willing to risk their safety with approaching cars. Because the time needed for a car to pass is rather short, pedestrians do not feel their freedom of movement is reduced much.

Pedestrians Crossing a Street Outside/Without Crosswalks

According to Finnish traffic law, pedestrians must cross the roadway along the crosswalk if there is one nearby; otherwise, pedestrians must cross the roadway at a right-angle to and preferably alongside the intersection. Pedestrians may not enter the roadway outside the crosswalk before they are sure that it will not cause danger or inconvenience to traffic. The law states that there are no special ordinances for motorists in this case. The laws in other Scandinavian countries are similar.

The governmental choice is to increase pedestrian safety by restricting the crossing points to crosswalks or to intersections, and by demanding that pedestrians give the right-of-way to other traffic. This choice increases freedom of movement for vehicular traffic.

In my survey in Helsinki 61% of pedestrians crossed the roadway inside the crosswalks and 39% crossed outside, but within 80 meters from the intersection (557 obs.). It happened very seldom that a car stopped and gave the right-of-way to a pedestrian in the crosswalks or outside.

If survey observations showed that a high percentage of pedestrians used the crosswalks, it may be explained by the fact that crosswalks are natural paths over the roadway for pedestrians using sidewalks. Another survey in Helsinki observed that none of the pedestrians used crosswalks when moving from one block to another.[3] On one suburban street where crosswalks were not available, 58% of the pedestrians crossed the roadway next to the intersection and 42% crossed outside, but within 80 meters from the intersection (81 obs.).

Therefore, survey results suggest that pedestrians use the crosswalks mainly in the most convenient way for them; otherwise, they cross the roadway outside the crosswalk or outside the intersection. In this way, the pedestrians increase their freedom of movement at the expense of the safety level desired by the government. The pedestrians do not feel any significant difference in safety because also in crosswalks it is very seldom that a driver gives the right-of-way to a pedestrian. Outside the crosswalks the pedestrians almost always give the right-of-way to the cars as required by law. The obvious reason for such high compliance is that pedestrians do not want to risk their safety.

Cars at a Signalized Intersection

According to Finnish traffic law, the red traffic signal indicates that a vehicle is not allowed to pass the signal or the marked stop line. The red and yellow signals together indicate that red is changing to green immediately; the yellow traffic signal indicates that a vehicle is not allowed to pass the signal or the marked stop line. If a vehicle, however, has gotten so far that it cannot be stopped without danger, when the signal changes from green to yellow, it may pass by the signal and the marked stop line. Finally, the green traffic signal indicates that a vehicle may pass by the signal and the marked stop line unless it is otherwise prohibited by the traffic law. In this case the governmental choice for increasing the safety of both pedestrians and vehicles is to reduce drivers' freedom of movement by demanding that during red and yellow phases vehicles do not enter the intersection.

In a Helsinki survey 96,000 vehicles were observed. The vehicles entered various intersections during the various traffic signal phases as follows:[4]

• green	85.6 to 98.5%
• yellow	9.8 to 1.1%
• red	3.3 to 0.3%
• red-yellow	2.2 to 0.1%

For example, in one intersection 3.3% of vehicles entered during red phases, and in another, 0.3%. Other observations at other intersections ranged between these percentages.

In this case individual choices coincided very well with the governmental choices. Very few entered intersections during the red and red-yellow phases, and in this way increased their freedom of movement. The majority stopped and remained standing and in this way decreased their freedom of movement but increased their safety during red and red-yellow phases. The number of vehicles entering an intersection during the yellow phase can be rather high. It is then obvious that drivers are increasing their freedom of movement from that required by the law.

Cars At An Unsignalized Intersection

In the majority of urban intersections in Scandinavian countries, there are no traffic signs or signals to show who has the right-of-way. According to traffic law, the right-of-way is to be given to the one approaching from the right-hand side. The governmental choice in this case is to decrease the freedom of movement for the driver approaching from the left-hand side. The obvious aim is to increase safety.

In my surveys, 63 conflicts were observed in Helsinki and Oslo. In 40% of these, the person who had stopped was approaching from the left, and in 60%, the person who stopped was approaching from the right. In another survey in Helsinki,[5] it was noticed that larger streets had a so-called psychological right-of-way at the intersections with minor streets.

In this case the individual choices do not coincide with the governmental choice. Those approaching from the minor street are willing to decrease their freedom of movement more than legally required, and those driving in the major street, less. The reason for this behaviour is obvious. The person approaching from the minor street has a lower speed than the one approaching from the major street. Because of that, stopping means an increased loss of time for the person on the major street. The person on the minor street feels that a car approaching at a higher speed is a risk to his safety. The person on the major street cannot sense a danger posed by a car approaching with relatively low speed from the minor street.

Cars at an Intersection With a Yield Sign

According to law, vehicles approaching an intersection from the direction controlled by a yield sign must give right-of-way to the traffic which is in the intersection or is approaching from the road which has the right-of-way. The governmental choice in this case is to reduce freedom of movement for the drivers coming from the direction controlled by the yield sign. Its aim may be to increase freedom of movement for the drivers on the other street while increasing overall safety.

Individual choices coincide, according to these observations, with the governmental choice when there is a clear difference in the characteristics between intersecting streets. This behaviour is normal for drivers because of approach speeds. The person stopping on the minor street loses less time than would the other person on the major street. The first person also perceives a danger with the other person approaching at a higher speed.

Summary of Surveys

The items of the previous pages are gathered in Table 1. On this basis the following principles were formulated:

- The government reduces individual freedom of movement and by that increases safety. Also, freedom of movement for some groups may be increased.

- Individuals increase their freedom of movement if doing so does not mean an obvious risk to their safety, and they decrease their freedom of movement if there is an obvious risk to their safety.

- Individuals obey governmental statements if the government reduces freedom of movement for those exposed to an obvious risk, or if the government increases freedom of movement for those not exposed to an

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TABLE 1

GOVERNMENTAL AND INDIVIDUAL CHOICES BETWEEN SAFETY AND FREEDOM OF MOVEMENT (FoM)

THE STUDY OBJECTS	THE GOVERNMENTAL CHOICES BETWEEN SAFETY AND FREEDOM OF MOVEMENT	THE INDIVIDUAL CHOICES BETWEEN SAFETY AND FREEDOM OF MOVEMENT	WHY DO OR DO NOT THE INDIVIDUAL CHOICES COINCIDE WITH THE GOVERNMENTAL?
1.1 Pedestrians crossing a street along a signalized crosswalk and facing a red pedestrian signal indication	• to reduce pedestrian FoM • to increase pedestrian safety	• pedestrians increase their FoM (from the governmental)	• risk for their safety is not obvious
1.2 Pedestrians crossing a street along a signalized crosswalk (with cars turning)	• to reduce drivers' FoM • to increase pedestrian FoM and safety	• pedestrians decrease their FoM • drivers increase their FoM (from the governmental)	• risk for their safety is obvious • risk for their safety is not obvious
2.0 Pedestrians crossing a street along an unsignalized crosswalk	• to reduce drivers' FoM • to reduce pedestrian FoM • to increase pedestrian safety	• pedestrians decrease their FoM • drivers increase their FoM (compared to each other)	• risk for their safety is obvious • risk for their safety is not obvious
3.1 Pedestrians crossing a street outside crosswalk	• to reduce pedestrian FoM • to increase pedestrian safety	• pedestrians increase their FoM	• risk for their safety is not obvious
3.2 Pedestrians crossing a street without crosswalks	• to reduce pedestrian FoM • to increase pedestrian safety • to increase drivers' FoM	• pedestrians decrease their FoM • drivers increase their FoM (as stated by the government)	• risk for their safety is obvious • risk for their safety is not obvious
4.0 Cars at a signalized intersection	• to reduce drivers' FoM • to increase drivers' safety • to increase pedestrian safety	• drivers decrease their FoM (as stated by the government)	• risk for their safety is obvious
5.0 Cars at an unsignalized intersection	• to reduce drivers' FoM • to increase drivers' safety	• drivers increase their FoM on the major streets • drivers decrease their FoM on the minor streets (from the governmental)	• risk for their safety is not obvious • risk for their safety is obvious
6.0 Cars at an intersection with a yield sign	• to reduce drivers' FoM • to increase drivers' safety • to increase drivers' FoM (on the major streets)	• drivers decrease their FoM on the minor streets • drivers increase their FoM on major streets (as stated by the government)	• risk for their safety is obvious • risk for their safety is not obvious

obvious risk. The individual behavior and governmental choices do not coincide if the government reduces freedom of movement for those not exposed to an obvious risk or increases freedom of movement for those exposed to an obvious risk.

It is obvious that safety and freedom of movement are closely interconnected both in governmental actions, law, engineering features, etc., and in individual behavior. Hence, when looking at transportation system performance, both safety and freedom of movement must be considered. Also choices at both the governmental and the individual levels must be considered.

Discussion

The understanding of the principles cited above can improve governmental policy decisions on both safety and freedom in the following ways:

- Recognizing that both safety and freedom of movement must be the basis for policy decisions, actions can be better directed and consequences can be analyzed with a broader scope. For example, if safety is improved by a reduction of freedom of movement, the analysis would be very poor if this reduction would not be considered.

- Governmental actions have different effects when looked at from the viewpoint of various groups. The understanding of these relationships makes it possible for the government to distribute the available resources according to the wanted policy. Without that knowledge the distribution would be arbitrary.

- The understanding of the way individuals make their choices between freedom and safety gives proper direction to governmental actions. Otherwise, actions may fail if the governmental and individual choices fall far apart, for example, if freedom is reduced when people feel safe.

- Individual choices give limits to governmental actions. These limits are interconnected to the traffic environment. When changing the environment, the limits are changed too, but with traffic law the limits cannot be expanded much.

- Today large legal and police organizations are needed to get people to accept governmental choices. This depends on the realization that the huge gap between individual and governmental choices may help to redirect the work done by various governmental agencies.

As a conclusion, I think that a better understanding of the relationships between freedom of movement and safety and of the individual choices leads to better governmental policy and in that way to the best possible combination of freedom and safety.

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AN EFFECTIVE SPEED REDUCTION AS A GENERAL TRAFFIC SAFETY MEASURE IN URBAN TRAFFIC

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Abstract

Modern town and traffic planning principles have failed to solve the safety problems on arterial roads in urban areas. In Sweden and probably in most other countries, a very high portion of the pedestrian and bicycle accidents in urban areas occur on arterial roads. Safety measures, such as signalization pedestrian overpasses or underpasses, have not been very effective due to a misuse that seems impossible to overcome.

Vehicle speeds on arterial roads are generally too high. This means that there is practically no interaction between vehicle-drivers on the arterial and intersecting road-users. For instance, it is a fact today that almost no driver stops to let a pedestrian pass at a zebra-crossing. An important consequence of this is that vehicle-drivers on the arterial have a very low degree of attention paid to possible conflicts with intersecting road-users.

A first experiment is carried out where a non-signalized, four-way intersection is provided with speed-reducing mounds. The number of serious conflicts has dropped dramatically, especially those involving bicyclists and pedestrians. Vehicle speeds are low and very homogenized after the installation of the mounds. The implementation costs are less than a tenth of the cost for traffic signals. In addition, vehicle delays in this case are much lower due to the speed-reducing mounds than if traffic signals had been installed.

The results are going to be followed up by larger studies on stretches of arterial roads where mounds are going to be installed.

The basic hypothesis is that speed reduction can be used as an extremely safety-beneficial countermeasure for general use in urban areas with fairly small disbenefits.

Background

Traffic safety research at the department has, during the last years, focused very much on safety for unprotected road users on arterial roads in areas built before the sixties. The main reason for this concentration of effort is that modern town and traffic planning principles have failed to provide solutions for the problems encountered on this type of road. Besides, accidents are to a high degree concentrated in these areas. In Sweden, statistics indicate that about 70-80% of pedestrian and bicycle accidents in urban areas occur on main arterial streets.

The SCAFT guidelines, introduced in Sweden in 1968, are built on the principle that road traffic of different types and with different purposes should be differentiated and segregated; that is, motor vehicles should not be mixed with bicycles or pedestrians, and local traffic should not be mixed with regional or long-distance traffic. Since 1968 these guidelines have been applied in most new town-planning projects and they have proved to be beneficial for safety.

However, it has never been possible to apply these guidelines successfully to areas built before the introduction of the guidelines. Recently, three main countermeasures have been used to improve the safety of unprotected road users in such areas. These are:

1. signalization of intersections for partial time separation of different and conflicting road-users,

2. signalization of mid-block crossings for full-time separation of cyclists and/or pedestrians from car traffic,

3. pedestrian and bicycle under or overpasses for spatial separations.

The evaluation process by which the safety effect of these countermeasures are assessed is very poor, unfortunately. However, a number of examples which indicate some of the problems associated with different countermeasures follow.

Signalization of Intersections

It is hard to find proof that signalizing intersections improves safety for pedestrians. Two rather old studies are found. In the first the number of accidents before and after signalization of 21 intersections in London is analyzed[1]. Accident rates are calculated, i.e., the ratio between the number of accidents after and before are adjusted with regard to the general accident trend in the same districts as the observed locations.

While the total accident rate for all intersections is 0.60 with a significant difference on the 1% level, the accident rate for pedestrian accidents is 0.83 without any significant difference.

In the second study 12 intersections in Stockholm are studied in a similar way.[2] In this case the total accident rate for all intersections is 0.56 while it is 2.14 for pedestrian accidents. This means that these accidents are more than doubled. The pedestrian accident figures, however, are fairly small, seven accidents before and fifteen after the signalization.

With these studies as a basis, it seems difficult to prove the hypothesis that signalization of intersections has reduced the number of pedestrian accidents. The reason may be found in the following analysis of pedestrian accidents at signalized intersections.

TABLE 1

THE DISTRIBUTION OF PEDESTRIAN ACCIDENTS AT SIGNALIZED INTERSECTIONS ACCORDING TO CAR DRIVER AND PEDESTRIAN BEHAVIOUR

City	Number of intersections	Number of pedestrian accidents	Percentage of accidents where pedestrians walked against red	Percentage of Accidents where driver drove against red	Percentage of Accidents where both parties travelled against green
Stockholm	22	54	50	13	37
Malmo	12	41	41	12	47

Thus, most accidents were due to a disregard for the traffic regulations. There is obviously a great discrepancy between behavior anticipated by planners and actual behavior.

Signalization of Mid-block Bicylist and/or Pedestrian Crossing

No direct studies of the safety effects of this type of countermeasure are known to the author. However, two studies from Sweden clearly illustrate the problems.

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TABLE 2

PEDESTRIAN AND CAR/DRIVER BEHAVIOR AT MID-BLOCK SIGNALIZED CROSSINGS

City	On the marked crosswalk				Outside the crosswalk but less than 20 meters away from the crosswalk			
	Against Green Light		Against Red Light		Against Green Light		Against Red Light	
	#	%	#	%	#	%	#	%
Malmö	868	76	179	16	0	0	92	8
Gothenburg	55	24	70	31	15	7	88	38

City	Cars Stopping At Red Light		Cars Driving Against Red Light	
	#	%	#	%
Malmö	1340	97	43	3
Gothenburg	146	87	21	13

These studies seem to establish the general problem as one of traffic disobedience. Many studies have shown the extreme risks associated with walking or driving against red lights or with walking near but not within a signalized crosswalk. When risk-figures are applied to the shown figures for pedestrian and driver behavior, the rate of pedestrian accidents hardly drops when mid-block signalization is introduced. Instead, new types of accident problems arise. Horberg and Eriksson, for instance, have shown that pedestrians tend to focus more on conflicting car traffic in a non-signalized intersection than in a similar but signalized intersection where a large degree of the concentration is focused on the signals themselves.[3]

Pedestrian and Bicycle OverPasses or Underpasses

Many different studies have shown a low rate of use for overpasses or underpasses introduced as safety measures in established areas where at-grade crossing is an alternative (which is usually the case). Due to countermeasure misuse, the impact of the safety measures is heavily reduced.

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Conclusions Concerning the Present Organization of Road Traffic in Urban Areas

The question of the safety achievement of spatial/time separation for different types of road traffic, especially when the separation is added to an established road system, needs examination. Safety measures, such as the addition of signals during the last 20 to 30 years, themselves determine behavior. Interacting with other road users becomes secondary. This in turn has created a lot of sudden and unexpected conflicts with cars traveling at high speeds. This type of conflict often leads to serious accidents.

In this paper I strongly emphasize the need for an alternative urban strategy which puts to use total concentration/road user interaction. This strategy is built mainly on general speed reduction which allows road users to take responsibility for avoiding physical conflicts. This is the opposite of the present situation where high vehicle speeds mean that independent preventive action has become almost impossible. Many road users find themselves in situations where the possibility of taking part in safety measures is heavily reduced.

The Need for Evaluation Techniques

From a safety point of view, it is my belief that the present condition of urban traffic is due mainly to a lack of information of how and why motorists act the way they do.

The main reason for the lack of information is a lack of evaluation techniques. An analysis of risks from accident data has some important disadvantages:

- Accident statistics are a poor diagnostic tool, and therefore relevant countermeasures cannot be foreseen.

- It is very difficult to evaluate the safety effect of countermeasures when accidents are used as a basis for the evaluation.

Since the number of accidents is often too small, such a practice leads to the use of very complicated study designs. For practical work on a local level such studies are not even possible to carry out. To overcome these problems an indirect technique of measuring risk has been developed at the department.

This Traffic Conflicts Technique (TCT) is based on the hypothesis that there is a positive correlation between serious conflicts (as defined for the study) and police reported injury/accidents. The development and test of the technique is described in a 1976 research report.[4] This conflict technique makes it possible to make safety studies during a very limited time period (a couple of days) including descriptions of behaviors and events leading up to serious conflicts.

TCT was first introduced by Perkins and Harris at General Motors in 1968 and has since been developed in a number of countries during the last ten years. Interest in TCT has increased strongly during the last years. Due to this heightened interest and to direct international cooperation on this matter, a steering group was formed at a conflict workshop in Paris, France in 1979, with the author of this report as chairman.

General Speed Reduction as a Strategy for Improved Safety in Urban Areas

General speed reduction may be very beneficial from a safety point of view for four important reasons:

1. Lower speeds allow drivers to spend more time on each part of the process of information collection.

2. When a conflict occurs, lower speeds leave more time for avoidance maneuvers.

3. If an accident occurs, lower speeds mean less severe consequences.

4. With normal travelling speeds on arterials (50-60 km/hour) hardly any interaction between car drivers and other road users occurs. Interaction can be measured by the numbers of cars stopping at a zebra crossing to let pedestrians pass, which today is almost none. If a pedestrian misjudges the speed of approaching cars, drivers are neither mentally nor physically prepared to avoid an accident when speed is high. Therefore, reducing speed in urban areas may mean that interaction is re-established between different road users, and that all road users assume responsibility for taking accident avoiding action.

A First Experiment with Speed Reduction in an Ordinary Four-Way-Street Intersection

In this section there is a rather complete description of one experiment in the city of Malmo, Sweden (250,000 inhabitants). This is the first (known) experiment with speed reduction at an intersection which is fully examined from various perspectives. The intersection is located semi-centrally in the city.

The intersection is totally uncontrolled; that is, the right-hand priority rule is valid. Each of the two interesting streets carries around 4,000 vehicles a day. Pedestrian and bicycle volumes are great. Speed reduction was achieved by road mounds which were found to be effective in reducing speeds in other studies. The mounds were located as illustrated in Figure 1.

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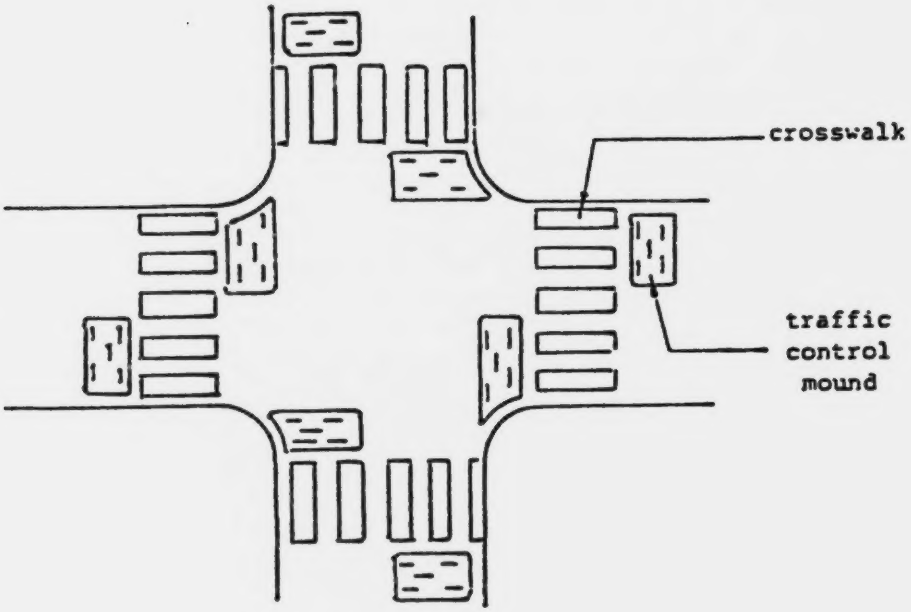
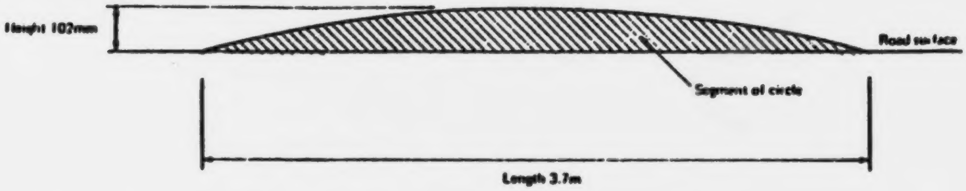
FIGURE 1


crosswalk
traffic
control
mound

The mounds are of the type recommended by the National Road Safety Department in Sweden, and were originally introduced and tested by Watts at TRRL in the United Kingdom.

FIGURE 1 (continued)


Height 102mm
Road surface
Segment of circle
Length 3.7m

Before and after-studies were carried out as follows:

Oct/Nov 1978	May 1979	Oct/Nov 1979	Sept/Nov 1980
Before-study	Mounds installed	After-study I	After-study II

Safety

The Traffic Conflicts Technique was used to enable a quick evaluation of safety effects and to enable more than one check after the installation of the mounds. Observations were carried out five weekdays in each study, five hours a day.

TABLE 3

THE NUMBER OF SERIOUS CONFLICTS BEFORE AND AFTER THE INSTALLATION OF THE MOUNDS

	Car-Car		Car-Bicycle		Car-Pedestrian		Total	
	#	%	#	%	#	%	#	%
Before	40	100	36	100	33	100	109	100
After I	18	45	9	25	5	15	32	29
After II	16	40	(29)*	---	10	30	(55)*	---

*Since the initial survey the number of bicyclists has increased by 60%.

In Table 3, the marked percent reduction in the number of serious conflicts for all types of road users is significant (at least on the 1% level) between the before and after studies.

The safety effect of speed-reducing mounds is strengthened by the fact that cars involved in serious conflicts travelled at lower speeds in the after studies. If the number of serious conflicts are converted to injury-producing accidents, then the safety effect of the mounds is markedly greater than illustrated by the conflict-figures.

Speeds

Speeds for approximately 6,000 vehicles were measured during two week days.

Mean Speeds for All Vehicles

	Private Cars		Heavy Vehicles	
	Mean (km/h)	Percent	Mean (km/h)	Percent
Before	20.6	100	20.0	100
After I	15.1	73	14.3	72
After II	15.8	77	14.9	75

The 85 percentile went down by approximately 10 km/h both for private cars and heavy vehicles.

Speeds were also calculated for different flows (left turners straight on, right turners from south, east, etc.). The difference in 85 percentile speeds for different flows went down from 19 km/h in the before study (38 km/h in the fastest flow and 19 km/h in the slowest flow), to 7 km/h (24 km/h and 17 km/h, respectively) in After I, and 6 km/h (23 km/h and 17 km/h, respectively) in After II.

It can be concluded from this study that the speed of all vehicles is low after installation of the speed-reducing mounds, and the range of vehicle speed within flows and between flows is small. Thus, speeds are homogenized and more compatible to that of bicyclists and pedestrians. In addition, the effect seems to be stable over time.

Vehicle Volumes

Following mound installation, the number of vehicles crossing the intersection decreased by 5%. The number of vehicles in similar areas where no changes were introduced decreased by 10%. Thus, it cannot be claimed that the mounds in this case caused a move of vehicles to alternative routes. It is also quite clear that the small reduction in vehicle volumes cannot explain the great reduction in the number of serious accidents.

Vehicle Delays

The calculations of actual delay caused by the mounds are derived from the speed measurements:

- actual vehicle delay caused by speed reduction due to mounds: 2.8 seconds

- theoretical vehicle delay caused by a signalization of the intersection: 6.7 seconds

Pedestrian and Car Driver Behavior

With mound installation, pedestrians wait less time for an acceptable time gap and are more likely to take "a distinct step out on the pavement" even if such a step causes a car to slow down (conflict studies, however, showed that this action did not create hazardous conditions). Car drivers tend to stop more often and let pedestrians pass when "pedestrians take an expectant step out on the pavement." Following mound installation drivers stopped for pedestrians 38% of the time as compared to 28% before installation.

Attitudes

Many different studies were carried out with people using roads for different purposes.

Most groups were very much in favor of the mounds. More than 80% of the car drivers that were interviewed stated that the mounds should be kept in this intersection, and almost as many (77%) thought that mounds should be installed in "many more similar intersections." Pedestrians and bicyclists were even more in favor of the mounds. Drivers of police cars, ambulances and motor fire engines, however, were less positive to the mounds. Only one-tenth of the two latter groups thought that mounds should be installed in "many more similar intersections," and about one third of the drivers of police cars thought the same.

Implications of Speed Reduction on Urban Transportation

Some important hypotheses can be offered based on the experience collected so far.

- The main hypotheses is that an actual speed reduction of 10-15 kilometers per hour will reduce the number of injury accidents to less than half.
- Waiting time for all road users crossing arterials will be heavily reduced, which among other things means a conservation of fuel.
- Capacity will increase when speeds are reduced to 35-40 kilometers per hour with less need for signalization of intersections.
- Lower and more even speeds will lead to a more comfortable way of driving with fewer operational difficulties.

These and other hypotheses are going to be tested in an ongoing project at the department in which the effects will be compared in "before" and "after" studies, on a number of arterial streets, where the present mean speeds are 50-60 kilometers per hour. To carry out the experiment, speed reduction can be achieved in may different ways. However, the only countermeasure that is known to give an actual speed reduction in a short time and without great costs is the use of road mounds.

Speed reduction can be used as a general measure for organizing road traffic in built-up areas. In principle, the ideal speed can be decided for each part of every road. The criteria used to decide ideal speed should be based mainly on the safety of different kinds of road users and on frequency of use. Another criteria might be the unattractiveness of certain roads subjected to vehicle delays. In principle, all roads should be provided with speed-reducing mounds so that ideal road speed is maintained.

This strategy is somewhat in opposition to principles used in Sweden and other countries today in order to decrease car traffic. This reduced traffic is achieved by introducing one-way streets, road blocks, cul-de-sacs, etc. All of these countermeasures make orientation very difficult. Besides, most trips include shorter or longer detours. On the other hand, speed reduction should be used as the only measure and should not include any closing of streets, etc.

Finally, I want to make a general remark about speed reduction. It is my belief that the top speeds on rural roads in almost all countries have fallen much more dramatically during the last five to ten years than what is proposed in my general speed reduction for urban areas. Besides, the speed limits on rural roads seem to be well accepted today.

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THE RISK CONCEPT IN ROAD SAFETY WORK

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Abstract

The analysis of accident data, that is historical data, is made basically in order to predict future accidents. Experience shows that quite often accidents may be predicted statistically.

The circumstances leading to accidents depend on environmental conditions: traffic flow, road layout, weather, police enforcement, etc. The author uses statistical statements which show the relationship between the expected number of accidents and external conditions.

From these statistical statements, the risk concept emerges which provides a probability of an accident given a certain activity or exposure.

In road transport systems this concept has been used widely and applied successfully.

The risk concept may be used under many circumstances. The paper illustrates the usefulness of the risk concept through examples which show that different risk definitions illustrate a problem from different points of view, that the chosen risk definition tends to influence thinking and policy, and that the risk concept has potential benefit as a tool in social policymaking.

Introduction: Basic Concepts

The analysis of traffic accident data, that is historical data, is made in order to guide our actions directed at the reduction of future accidents. In general, we may state that the purpose of the study of accidents is to create the possibility of forecasting future accidents. Our interest in the tragedies of the past comes out of our interest in avoiding future tragedies.

As has been shown in multidisciplinary accident investigations, each single accident constitutes a small universe of personal conditions, physical conditions, and random events. However, accidents occur in such numbers that all of these apparently unique conditions occur over and over again. Experience shows that these circumstances are recurrent events. Since "History repeats itself," it is possible to predict accidents statistically.

The treatment of accidents requires data reduction from many small universes to fairly simple relationships. This process is necessary because it will reveal common factors. The common factors, rather than individual differences between accidents, are the keys to prediction.

The circumstances leading to accidents--including road user behavior--depend on physical and social conditions: traffic flow, road user categories, road layout, roadway conditions, traffic codes, law enforcement, etc. These and other factors have been studied in detail, so it is possible, at least in principle, to set up a relationship between expected accidents and external conditions, such as

$$E(U) = f(x_1, x_2, x_3 \ldots\ldots x_n) \qquad \text{Equation 1}$$

where $E(U)$ are expected accidents and $x_1 \ldots\ldots x_n$ are variables representing external conditions.

The reason we set up such a relationship is that we wish to predict accidents under conditions which do not correspond to the conditions for which data have been collected. A functional relationship as represented by Equation 1 is a generalization of accident experiences which enables us to predict accidents under conditions which differ clearly from those about which data are collected.

A very simple relationship would exist if there were only one independent variable in Equation 1. The risk concept can be interpreted as the hope that there exists one activity variable which is dominant, so that the expected number of accidents may be written as

$$E(U) = R \cdot X \qquad \text{Equation 2}$$

where R is a constant and X is the dominant activity variable. When written in this form, it appears tempting to consider R a fraction of those situations X, where an accident may occur, and thus the familiar formulation

$$\text{Risk} = \frac{\text{Accidents}}{\text{Exposure}} \qquad \text{Equation 3}$$

is no more than Equation 2 rewritten. In Equation 3 the dominant variable is called Exposure while the constant, called Risk, expresses how frequently an accident occurs per unit of exposure.

It should be stressed here that if this risk concept is used for practical purposes, the Equations 2 and 3 must be good approximations of Equation 1. If Equation 3 is not a good approximation of Equation 1, then the use of Equation 3 will show inaccurate predictions of accidents with respect to alternative choices between policies. This may in turn lead to erroneous estimates of benefits and to mistakes in allocating funds for accident reduction work.

Practical Applications in Traffic Engineering

Accident Rates on Road Sections

The risk concept has been applied successfully in predicting (modeling) accident data on road sections. It is well known that

$$R = \frac{\text{number of observed accidents}}{\text{vehicle kilometers travelled}}$$

is approximately constant given a certain road layout. This concept is equivalent to the commonly used accident rate. Different roadway elements such as median strips, auxiliary lanes, etc., each have certain relative effects (percentage effects) on accidents, and these effects do not depend on other elements. Therefore, the effects of such elements are independent factors in an equation, such as Equation 1.

In the Danish design standards for the selection of cross sections for rural roads, this fact is used to set up a computational procedure for forecasting accident rates (risk) for all cross sections and all road classes permitted within the standards (Reference 1). However, if Danish accident data are studied in detail, the accident rate on two-lane roads is not a constant but, in general, slightly decreasing with increasing flow.

Intersection Accidents

So far it has not been possible to reach a scientific agreement on the relationship between accidents and traffic flows at intersections. While it seems reasonable to put the intersection flows in the denominator in Equation 3, it is difficult to see how flows should be measured to establish an exposure concept which makes Equation 3 a good approximation, that is, a formula by which accidents can be forecasted as a function of traffic flows.

If we consider an intersection with random arrivals in both directions, we might assume that the number of accidents are proportional to the number of times two crossing vehicles come within a certain time limit of each other. This assumption would mean that accidents are proportional to $N_1.N_2$ where N_1 and N_2 are the crossing flows. However, the accident number increases less with traffic than $N_1.N_2$ indicates. Dependence on the smaller flow is much stronger than on the larger flow. (References 2,3). In order to take care of different observations, a number of relationships have been suggested, such as

$$E(U) = K.(N_1+N_2)$$

$$E(U) = K.N_1 \cdot N_2$$

$$E(U) = K.N_1^a.N_2^b$$

In the latter equation constants (a) and (b) are found by means of regression methods. To make things even more complex consider the number of bicycle and moped accidents at intersections. To establish relationships, it seems reasonable to take into account car, moped, and bicycle flows. Furthermore, it may not be realistic to make an assumption about how close to each other the vehicles come, if they move independently, because clearly they do not move independently. It may be more interesting to consider the number of times a vehicle from one direction follows a vehicle from the other direction. This assumption suggests a formula like

$$E(U) = K\frac{N_1.N_2}{N_1+N_2}$$

If this assumption is made and we look for the number of bicycle accidents, that is accidents involving cars and mopeds against bicycles, we arrive at

$$E(U) = K\left(\frac{C1\cdot B2}{C1+B2} + \frac{C2\cdot B1}{C2+B1} + \frac{M1\cdot B2}{M1+B2} + \frac{M2\cdot B1}{M2+B1}\right)$$

where C1, M1 and B1 are car, moped, and bicycle flows in one direction in the intersection, while C2, M2 and B2 are corresponding flows in the other direction.

These examples, which represent classical traffic engineering thinking, are given in order to show that there are many possibilities which may have a certain amount of logic or empirical data to support them. Considering the number of accidents which occur at intersections, we should be concerned about our lack of knowledge in this field.

Practical Applications in Other Fields

The following examples are given in order to show that:

1. the risk concept to be used depends on the problem in question and on the fact that different people (authorities, interest groups) may well use different concepts and therefore different data sources;
2. the risk concept chosen tends to influence thinking and policy; and
3. the risk concept is useful in policymaking.

Health Risk and System Risk

Suppose we asked the question, "what is the risk to a moped rider in Denmark?" At least two different approaches are possible:

R1: $\dfrac{\text{injured moped riders per year in Denmark}}{\text{inhabitants in Denmark}}$

R2: $\dfrac{\text{injured moped riders per year in Denmark}}{\text{kilometers by moped per year in Denmark}}$

R1 measures moped risk as a health risk. Evaluations of the Figure R1 would probably involve comparisons to injury risk in other activities, risk differences between age groups, risks due to diseases, etc.

R2 is a figure measuring the quality of the traffic system. It might be called system risk. Comparisons would be risks to other road users, risks on different categories, etc.

If we choose to consider R2, it quickly becomes apparent that the risk is extremely high to young riders (ages 15, 16 and 17). Under these circumstances society may react by raising the legal age limit for moped riders. This in turn may lead to fewer accidents due to less exposure, but the questions are: "do young people ride mopeds more than other people do?" and, "is moped use particularly beneficial to them?"

If we choose R2, we will find that the risk is associated with road layout at intersections, with alcohol, with week-end evenings, etc. Given these circumstances, society may react by improving the road system or by initiating some alcohol propaganda program actions which influences all moped riders. Implicit in such policies is the consideration that all moped kilometers are equally useful or necessary.

In fact, R1 was chosen in Denmark for policy purposes, and the legal age limit was raised from 15 to 16. But the question of benefits to 15 year olds resulting from riding mopeds was hardly mentioned in the public debate.

Risk in Urban Bus Transport

It is well known that riding a bus is fairly safe. But what is important when we choose this mode of transport?

Since a work trip in any case includes some walking, some vehicular transport and some additional walking, it may be argued that the important risk to the individual is his/her expectancy of an accident during one work trip, such as

$$E_1(U) = E_1\ (U,\ \text{walking}) + E_1\ (U,\ \text{driving/riding})$$

where $E_1(U)$ is the accident expectancy to one person during one work trip.

To society it is important to note that a work trip also imposes risks to other road users, that is, a car trip imposes a risk to mopeds and bicycles outside the car. The total accident risk from a work trip,

$$E_2(U) = E_2\ (U,\ \text{walking}) + E_2\ (U,\ \text{driving/riding})$$

therefore is greater than $E_1(U)$. For a typical work trip in the Copenhagen area, either by bus or by private car--involving different walking distances--the risk may be calculated, see Figure 1 (Reference 4). Based on data available in 1974, the Figure shows that to individuals the risks by car and by bus are roughly equal. Therefore car drivers have no incentive to take the bus for their own safety. However, to society there is an overall safety benefit which comes from persuading car drivers to take the bus. Again the risk concept is important. Different people will tend to use different risk concepts and in fact may arrive at opposite conclusions using identical data sources.

Defining Objectives in Risk Terms

In recent years the formulation of objectives related to traffic safety work has been the subject of discussions in the Scandinavian countries.

In Finland a very ambitious objective in terms of the absolute number of fatalities was formulated in the mid-1970s, stating that fatalities in 1981 should be no more than half the 1971 figure (Reference 5). Figure 2 indicates significant progress compared to that of other Scandinavian countries. Most objectives, however, have been formulated in risk terms.

One of the benefits arising from formulating objectives in risk terms is that a number of comparisons become possible. Comparisons among components of a traffic system are clearly useful (between road user categories, road categories, etc.). But also comparisons of risks resulting from other activities, such as risks at work, sporting risks etc., are useful in defining broader social objectives. Therefore, risk objectives may be stated as either absolute or relative and in terms of systems risks or social risks.

A few examples of comparisons related to such objectives, which are really policy statements, are given:

From Norway (Reference 5)

1. Road users such as pedestrians and bicyclists who impose little risk on other road users should have a lower accident rate than car drivers.

This is a relative systems risk objective.

2. No road section (>2 m) should have an accident rate over 2.0 accidents per 10^6 Vkm.

This is an absolute systems risk objective.

3. Road user risks should be comparable to risks in industry and at home.

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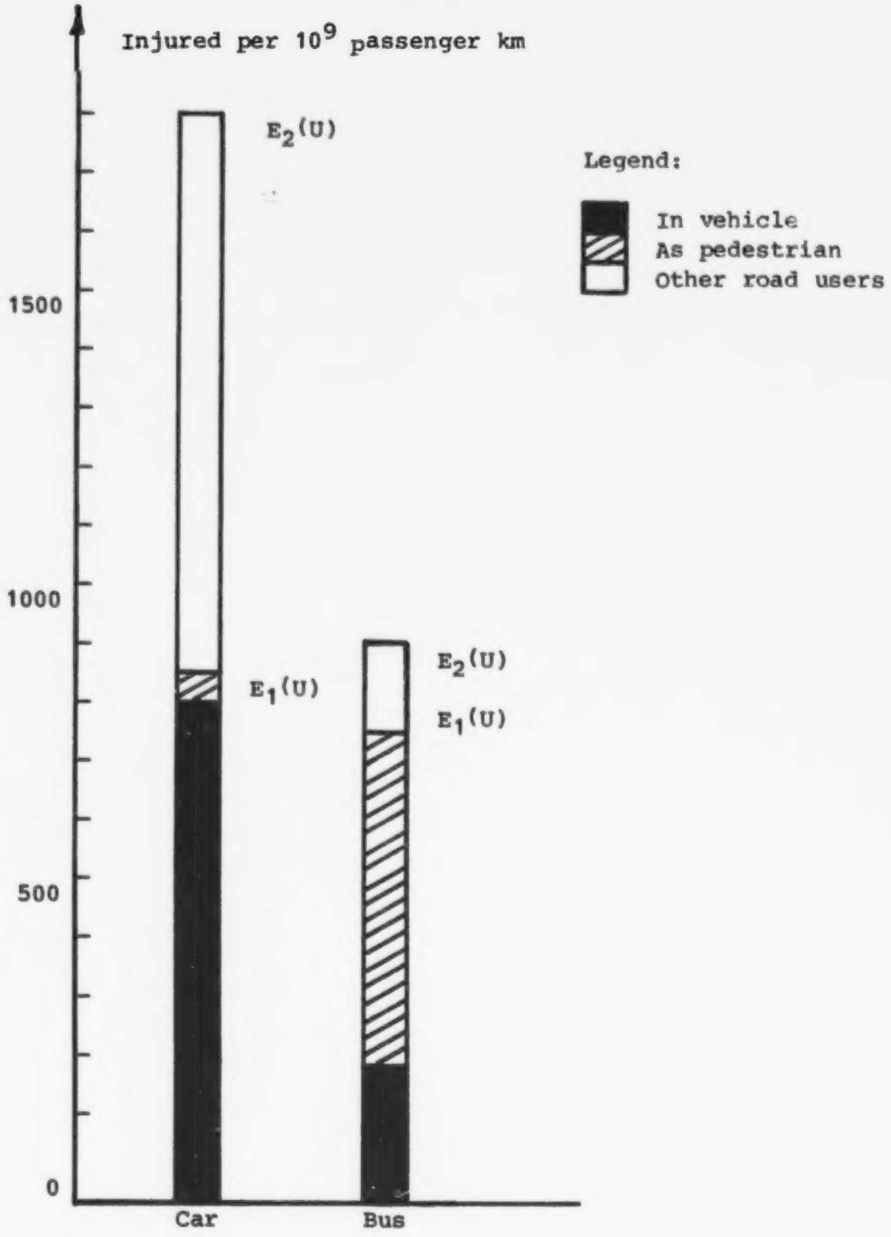
FIGURE 1



Accident risks using different means of transport

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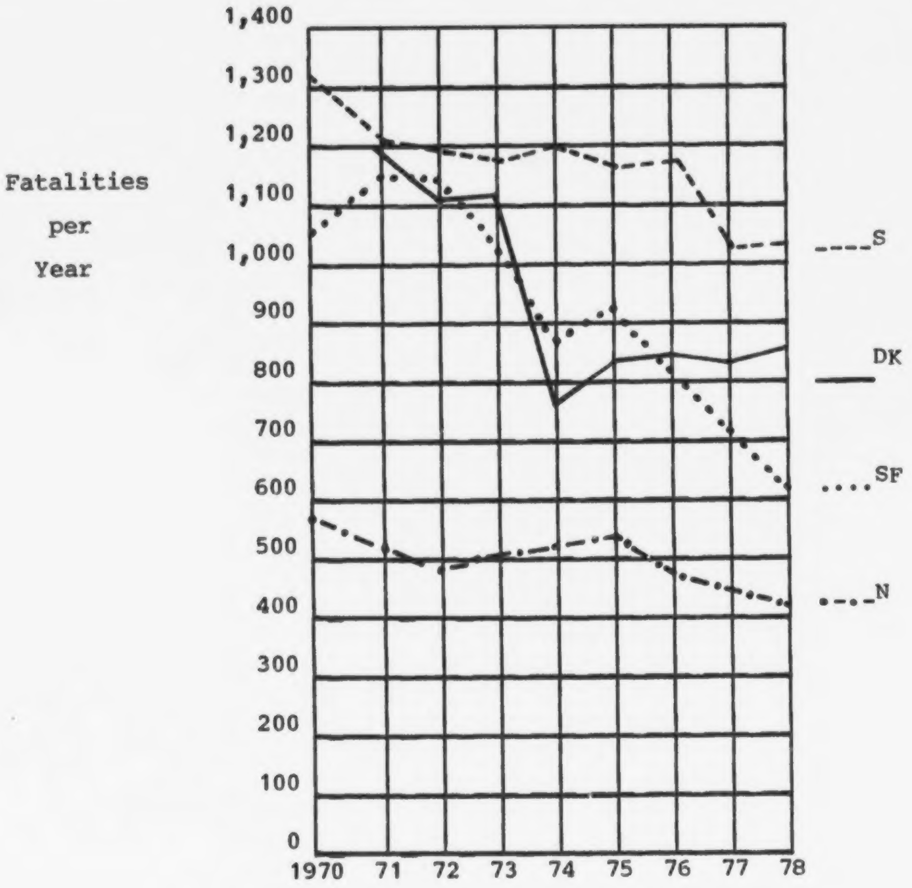
FIGURE 2



Trends in traffic fatalities in four countries

S = Sweden
SF = Finland
DK = Denmark
N = Norway

This is a relative social risk objective.

From Sweden (Reference 6)

1. The risk indicators for all road user categories should be reduced continuously.

This is a relative systems risk objective.

2. Before the end of the 1980s the number of injuries in road traffic should be reduced by 30 percent.

This is an absolute systems risk objective.

In the Scandinavian countries, other examples exist and more are expected to be stated, both at national and local levels. These cases show that the risk concept has potential benefit as a tool in making policies both within the traffic system and in distributing safety standards between different social systems.

Conclusions

1. The risk concept is useful for generalizing accident experiences. An important use is for predicting accidents in decision processes, a choice between alternatives.
2. Accident rates are risks. They have been used widely in Traffic Engineering practice. It is a matter of concern that little is known about the relationships between traffic flow and accidents at intersections.
3. Risk concepts can be tailored to the political problem in question, but the chosen risk concept tends to influence thinking and policy.
4. The risk concept has potential benefit as a tool in social policy-making, that is in distributing safety systems between different systems in society.

Acknowledgments

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A METHODOLOGY FOR TRANSPORTATION SYSTEM SAFETY

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Abstract

Under contract to the U.S. Department of Transportation, a methodology for addressing transportation system safety was developed and was the prime focus of the "First National Symposium on Transportation System Safety," held in May of 1979. The Symposium was jointly sponsored by the U.S. Department of Transportation, the Transportation Research Board and the Polytechnic.

The safety approaches used in Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) were initially reviewed including, but not limited to, the new and powerful safety analysis techniques developed in applications in those areas. Both the sponsors and the researchers were very interested in the "technology transfer" from such applications.

The methodology which developed is rooted in a sound and systematic management approach to safety. This includes proper recognition of the safety function, interaction, feedback, and responsibility. It also includes proper and appropriate use of quantitative methods--reliability, fault analyses, and the techniques of the behavioral sciences.

Several case studies were executed on different levels and with different foci--an entire rail rapid transit property, a highway facility, and the pilot-air traffic controller interface. The balance of management, personnel interaction, organization priority, and the need for supporting quantitative methods and information was explored extensively.

Introduction

The problem of transportation safety encompasses all modes, all classes of population, all economic levels, and all transport purposes. The history of transportation is replete with examples of such problems:

- periodic tragedies of air crashes involving larger and larger aircraft;

- freight trains, carrying hazardous materials, involved in accidents with potentially catastrophic results;
- subway trains colliding or malfunctioning;
- modern rapid transit, commuter rail vehicles, and buses delivered with serious errors and faults in design; and
- tens of thousands of automobile accidents.

The list could go on indefinitely.

These problems present a great need for a systematic methodology and its application to the industry as a whole, rather than a reliance on traditional approaches. Such current methods and approaches to safety in the field of transportation rely heavily upon two basic procedures:

- preventive design considerations and
- study of accident experience.

These two methods have had their successes, but the fact that we are still searching for new approaches to safety is an indictment of their limitations.

During the years of the aerospace boom, engineers involved with such unique programs developed a new conceptual approach to safety known as "system safety." The U.S. Department of Transportation, in its continuing effort to develop an answer to the safety problem plaguing the transportation industry, decided to study, transfer, adapt and tailor the "system safety" approach to transportation.

With the foregoing in mind, the U.S. Department of Transportation, Office of the Secretary, entered into an agreement with the Polytechnic Institute of New York to develop a Transportation System Safety Methodology applicable to all modes. This was accomplished in three distinct phases:[1]

Phase I: Identification of key issues, and preparation of a preliminary Transportation System Safety Methodology applicable to all modes

Phase II: Testing the applicability of the transportation system safety concepts developed during Phase I in various case studies, and further resolution of key issues

Phase III: Refinement and preparation of the methodology in the form of generalized guidelines

This methodology was the focal point of the "First National Symposium on Transportation System Safety," held in May of 1979 and jointly sponsored by the U.S. Department of Transportation, the Transportation Research Board, and the Polytechnic.[2]

The method developed is a composite of material from a number of disciplines which include, but are not limited to, management, statistics, system safety, reliability, information theory, and behavioral psychology. Our task was to find applications of system safety to transportation, and we created an all-inclusive methodology, of which system-safety techniques became a few of the many tools used in a comprehensive management and technical approach to overall transportation system safety. This new approach, admittedly constructed from existing concepts, considers the totality of all transport systems and all their safety aspects.

The method as conceptually developed does not depend on large infusions of money. It represents, in some cases, the need to add staff, but staff that should have been there anyway. In other cases, it represents the need to introduce or expand the use of computers in a given operation, but that is long overdue anyway. Finally, it represents the need for existing personnel to expand their knowledge in certain areas, areas which they know they should have learned something about a long time ago.

The method stresses the proper allocation of resources of time, effort, and money to those areas that require improvement, and those areas where a reasonable payoff is expected. Whether it is identified as cost-benefit, cost-effective, cost-utility, or resource allocation, this approach is of utmost importance in these times.

The methodology heavily emphasizes the role of management. While new (and old) concepts are introduced in technical aspects, none of them will be effective unless management, from top to bottom, embraces and adopts the methodology wholeheartedly and makes it its very own. The attitude of management is all-important. The attitude of management affects and directs the attitude of all the effectuators of the transportation system safety process.

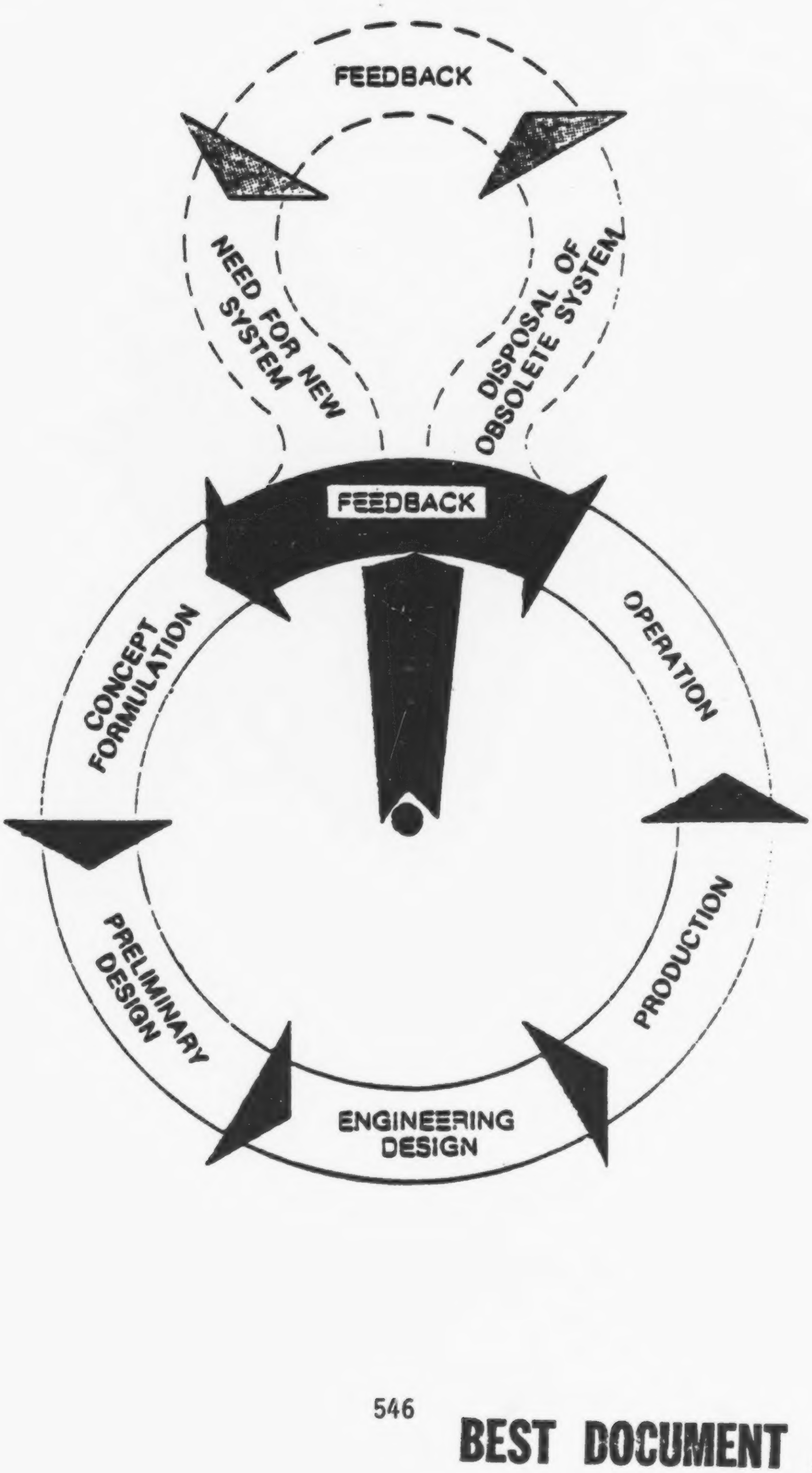
The System Life Cycle

Generally, a transportation project can be divided into several parts, based on its evolutionary development. There are five distinct levels attached to a transportation system activity cycle: the conceptual level, the contractual and preliminary design level, the engineering design level, production or construction level, and finally, the operational and maintenance level. Refer to Figure 1.

This "system life cycle," which was originated by the military, has been adapted to the requirements of the transportation industry. It is all too evident in our design flaws and poorly performing new systems that we pay little attention to such a concept in transportation.

Information from the operation of the system can be fed back to adaptations as the system is updated and upgraded, as with new cars, new communications, or new signal systems on a rapid-transit property, thus the link to the conceptual level from maintenance and operation.

FIGURE 1
TRANSPORTATION ACTIVITY CYCLE (TAC) RING


FEEDBACK
NEED FOR NEW SYSTEM
DISPOSAL OF OBSOLETE SYSTEM
FEEDBACK
CONCEPT FORMULATION
OPERATION
PRELIMINARY DESIGN
PRODUCTION
ENGINEERING DESIGN

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In some cases, a total system may be discarded, due to obsolescence, and a new concept evolved from the experience, thus the "disposal" link in the cycle, although we must recognize that this is rarer in transportation than in military practice. At the same time, we cannot avoid noting that the current state of maintenance of some transportation systems is tantamount to discarding them.

Each segment of the "Transportation Activity Cycle" must have its transportation system safety activities to ensure that there is no oversight in important areas of safety. Feedback is the watchword. It is necessary to use the knowledge that is developed every day in regulation, planning, design, operation, and maintenance and apply it at every step of the way. The lessons learned from years of operation of the Boston rail rapid transit system or the design of the Bay Area Rapid Transit (BART) system should not be ignored in designing any new rail service.

The Methodology

The Transportation System Safety Methodology is a management tool, reinforced by analysis procedures for identifying the potential areas of failure in the system. The methodology is pursued by developing a program plan which requires:

- system definition;
- a determination of organizational structure and responsibilities;
- the setting of safety policies, goals, and objectives;
- selecting, training, and certifying employees;
- identification of hazards and their control (this of course includes accident analysis as the prime hazard identification procedure); and
- the creation of an appropriate data base for documentation requirements.

We must recognize that accident data are a source of hazard identification and must be looked at as such even as we seek less traumatic means of identifying hazards.

Analytical techniques are used where applicable and where appropriate, but the overall management approach, properly implemented, should provide a more orderly approach to safety than we have today and should result in a saving of both effort and money.

The methodology is a body of principles, recommendations, guidelines, and checklists. It is made up of a management approach plus the technical tools for implementing it. Management is stressed as the framework for using those technical tools.

The method first provides for checking the management structure, policy setting, and the development of organizational goals and objectives. Safety responsibility and accountability must then be established, and the channels of information must be set to facilitate the flow of safety information from top management down the line to operating personnel and back, as well as horizontally. In addition, the selection, training, and certification of employees should be carefully designed and implemented to insure that the control elements in transportation facilities, the humans, have the appropriate skills to participate in the safe operation of a system.

Finally, employees, operators, passengers, pedestrians, and the general public must be motivated in various ways and different directions, but all towards a common goal: greater safety in travel.

Through a systematic approach to safety, potential hazards can be identified before they are activated. The thrust of a transportation system-safety approach is oriented towards action, rather than reaction. This is one of the main differences between the classical, conservative approach to safety, and the dynamic transportation system-safety approach. Accidents can be prevented, if necessary, and adequate action is taken to eliminate and control hazards.

A transportation system-safety approach does not imply that the system must be risk-free but rather that risks can be identified by management and controlled. Thus, the resources needed to design or redesign a transportation system, to meet specific risks, can be estimated at the outset and refined as work progresses. Development of data to support managerial decisions may be seen as one of the important roles of the system safety approach.

The Place of Safety

Safety is an integral part of a transportation organization, but that does not mean that "safety is everybody's business" in the usual sense. There must be a safety section or individual with purely safety responsibility, and for it to function effectively, that section or individual must be properly placed in the management structure.

Management's law of functional growth states that, as an organization expands, the complexity of the functions and communication lines which are necessary for performance increases even more rapidly. This situation calls for management to specify its requirements as clearly as possible.

Management defines two types of functions within an organization: line or mainstream functions, and staff or adjunct functions. The line functions are those that directly pertain to producing the intended output of the system. In a transportation organization, the intended output or "mission" is the transportation of people and goods. On the other hand, staff functions are activities that provide internal support and guidance to the line functions. They are intended to improve the efficiency and maintenance of the organization. In the context of an operating entity, safety programs, and especially a system-safety program, would be considered a staff or adjunct function.

The safety staff should be visible to all, and therefore should be located on organization charts, at the highest staff level, so that it cannot be considered part of a grouping of either line groups or other staff groups. From what we have found, safety traditionally has been a secondary staff function with little or no authority. It has been considered a dead-end in career advancement and has not always attracted the appropriate people to it. It is therefore necessary that the safety group, or individual positions, be considered stepping stones to career advancement in every organization to attract the most interested, ambitious, capable, and well-motivated people.

It is also necessary, however, to employ specialists in safety, and as a safety organization grows in size and complexity, there is an on-going need for engineers, analysts, inspectors, accident investigators, training specialists, behavioral scientists, emergency medical technicians, and others.

Safety should not only be built into a system, but it must also be under constant and impartial scrutiny. This creates the need for outside people to review and audit safety functions and safety-related activities, in addition to internal checks and balances.

To insure adequate safety performance, management must employ a continuous performance control system. Such a system is made up of four elements:

1. the establishment of goals and objectives,

2. the assignment of responsibilities and accountabilities for safety programs,

3. the provision of means for measuring and evaluating results, and

4. the provision of means of correction, when evaluations show the need for such action.

When accidents happen in spite of the existence of a safety program, the organization is being given a warning of shortcomings in the program or in its execution.

The limits of responsibility should be defined clearly. Overlapping tasks with unclear limits of responsibility usually account for high failure rates. Examples are uncontrolled intersections on highways, or the aircraft pilot-ground control interaction in the approach stages of a flight. On the other hand, no task or part of it should be left uncovered.

Responsibility is usually assigned through delegation by superiors, but responsibility thus delegated does not relieve the superior from his own responsibilities. Therefore, while safety functions are delegated to the safety staff, neither the responsibilities of top management nor line personnel have been removed.

Delegation of responsibility must be accompanied by the granting of authority. There is no effective responsibility without the authority to carry it out, and there is no effective control without accountability.

In safety management, it is of extreme importance to maintain single accountability. Divided accountability to several superiors disperses the effectiveness of the safety group or person and makes the job more difficult.

The Role of Quantitative Methods

The analysis techniques available for use in Transportation System Safety range from the most basic to the rather sophisticated and complex. They cover the spectrum of:

- those in common use;
- those in use in only some modes and unknown to most practitioners; and
- those in use (or available for use) in other, non-transportation specialties.

Some of the analytic techniques developed for U.S. National Aeronautics and Space Administration and Department of Defense fall into the last category.

Due to constraints of time and space, let us focus on some particular aspects of quantitative methods:

- Indices
- Effectiveness of Countermeasures
- The Role of the Behavioral Sciences
- The Training of Personnel

Even in these, we shall limit ourselves to provide you more with questions rather than answers, so that we may focus on the mission of this session--"Transportation System Safety State of the Art."

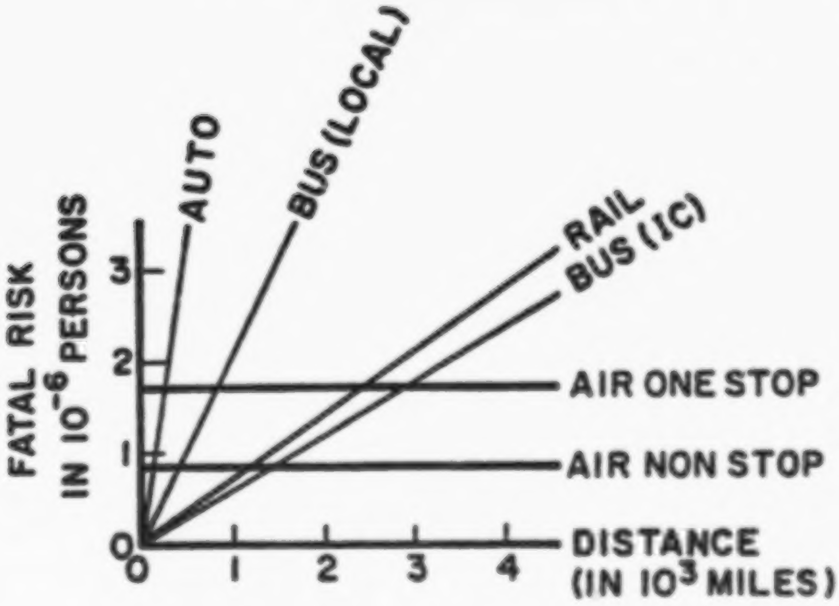
Indices

Much has been written and said on the subject of safety indices. This includes the issues of time versus event base, exposure rates and passenger versus system, and severity. We cannot resolve it in this paper, but we can raise the following question:

> "To what extent do erroneous indices set out transportation safety priorities and mislead our judgment?"

As one part of our own work, we constructed an intermodal safety index based upon fatalities only. This is displayed in Figure 2. The relative safety of various modes changes as a function of trip distance and is radically different than the common statement, "Commercial air travel is the safest way." How should such a view affect our decisions and perceptions? How does it affect yours?

FIGURE 2
PROBABILITY OF AN INDIVIDUAL'S FATALITY
AS A FUNCTION OF TRIP DISTANCE



Because the illustration shown in Figure 2 is different, let me take a moment to comment on its derivation. Every trip can be divided into a sequence of distinct "Environments," within which the risk is comparable or within which a single significant event takes place. For instance, a simple air trip can be divided into three such environments--takeoff, en route flight, and landing. If the weather, traffic level, type of control, or other risk- determining factor changes, the "en route" portion might be divided into several distinct environments, each of which has its own probability of an incident. Similarly, multiple stops introduce other environments through which the plane passes.

The concept of a sequence of distinct environments can be applied to any trip by any modes. Within the confines of existing data and its organization, the failure rates for each environment were estimated and served as the basis for Figure 2. Further details are provided by Byun et al.[3]

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It is especially interesting that such an approach can be used as the basis for structuring a data base and for directing the organization of future data. Indeed, the structure of the "model"--whichever "model" or "view of the world" is used--should logically determine data base structure and collection.

As a policy issue, we may ask ourselves how well we follow this logical pattern--develop and accept a "model", determine data base structure and requirements, and acquire and format data. Too often, information is available only on the basis of historical formats and detail, and we find our analyses limited by these structures.

Effectiveness of Countermeasures

Much time has also been spent on evaluating the effectiveness of various programs. Perhaps too little time has been spent on the questions of whether the probable effect can be measured, or if there are not other factors which will undoubtedly overwhelm it, even if it does exist. That is, one must ask: was there truly a change due to the countermeasure; or was the underlying pattern changing anyway?

If the trendline--or "base condition"--were changing, it is possible to deduce that a worthless countermeasure in fact was extremely useful. On the other hand, if the trend were going the other way, and its change not taken into account, a good countermeasure might be perceived as worthless.

Using the safety index just described, we considered major forces at work in our society and noted that they alone can have major influences on the highway safety record. For instance, the aging of the population can lead to a decrease of up to 10% in the accident rate, because the percentage of drivers in the highest accident years will decrease as the population ages!

The Role of the Behavioral Sciences

There is a conventional body of analysis referred to as Human Factors Engineering. In transportation, this tool is of concern in:

- the interior design of operators' environments, ranging from the automobile to the airplane;

- the design of the guideway to provide necessary information and adequate visibility to the operator, ranging from roadway "sight distance" to railway signal locations.

Without minimizing any of the efforts necessary in this important field, it is vital to pay at least as much attention to the functioning of the human person, and not simply to the relation of the human to devices. The field of human behavioral psychology is devoted to just this aspect: humans are perceived as responding to stimuli and conditioning their future behavior upon the reinforcement--or the absence thereof--due to their responses. This behavioral view can provide valuable insights.

Within the framework of behavior theory, there are also a number of useful techniques for specific analyses:

- content analyses of speech, including word rate and rates of self-correction;
- a "what if" analysis of test subjects, eliciting their responses as particular stimuli are put to them.

In our own work, we found the rather interesting result that pilots and air-traffic controllers have more self-corrections in their interactions during light traffic than during heavy traffic. It raises the behavioral question of whether this is due to poorer performance during the less active times, or whether it indicates a "suppression" of needed corrections during the heavy traffic times.

Behavioral psychology is one of the bodies of knowledge which can provide much insight into the human interacting with the environment. For instance, the continual checking of a platform by a trainman is usually not reinforced by detecting a passenger in danger. Indeed, the fact that the checking took place goes unnoticed and unreinforced. It is to be expected that such behavior--the checking--will slowly disappear.

The Training of Personnel

Much could be said of the need for systematic training of personnel, certification, recertification, and checking. However, let us simply note the special problem of training for a crisis reaction.

We are all doubtlessly familiar with the use of simulation in various ways. In the present context, it is probably sufficient for us to note that simulation can be used in three ways:

1. To promote understanding. By taking the care necessary to precisely specify a simulation, the analyst and the practitioner learn to better understand the system. Further, they can exercise the simulation to gain yet additional understanding;
2. To test designs. Given a trustworthy simulator, one can consider modifying design features or practices in ways which might not be safe or cost-effective in the real world;
3. To train personnel. Simulators can be used to train personnel in routine procedures, and in crises reactions, to varying degrees of success.

While each of these merit recognition, the concept of training personnel to react to crises is particularly enticing. It is the nature of serious accidents that they occur rarely, and that the operating personnel involved generally experience few such situations in their lifetime. In electric utilities, personnel are told procedures for shedding electrical load rapidly in a crisis, but rarely have to do it. When called upon to act in a real emergency, the lower-level employee actually operating the control room must decide within a few minutes whether to really shut down a major section of a city on his own authority and judgment. Certainly the potential for "crisis training," to make it easier for the action to follow the abstraction, is attractive. On the other hand we must recognize certain limitations, such as with experienced airline pilots who know that no matter how severe the simulation, they will survive a "failure."

Issues and Implications

To date, we have applied the methodology in case studies on three "systems":

1. a rail rapid transit system, which was the most self-contained and "complete" system;
2. a highway facility, which is a system characterized by drivers and vehicles whose standards or licensing are not under the control of those in nominal charge of the system; and
3. the pilot-air traffic controller interface, which is a singular, highly focused, and precisely defined system which is in fact simply one key sub-system.

The results of each case study are available for interested parties.[4,5,6] These served to refine the original concept of the methodology and to emphasize the role of management policies and functions.

We have raised a number of issues related to transportation system safety, and wish to close by raising some additional related points:

- Are our procedures complete and rigorous enough? Do we need special training procedures in crisis situations, such as a simulator, to expose people to the need for early response or to acquaint them with the limitations of their equipment?
- Do we actually have effective training and certification procedures? That is, can we believe that people know what they are supposed to know?
- Is there an adequate system of "checks and balances" to assure that procedures are effective, and that they are respected by those who should check as well as by those who should use them?
- Is the use of more automation and gadgets good or bad?

We must also recognize that some factors exist which circumscribe what can be done, or more precisely, what is frequently done. If it is necessary that these factors be overcome as part of the safety effort, it must be recognized that to overcome them requires a major effort, which is sometimes difficult. Consider, for instance:

- labor agreements, which limit the amount of "history" which can be kept on workers' job performance or incidents, or which can be used in an evaluation;
- operational concerns with "getting the train through" without unjustifiable delay, which set a certain tone for what the workers are expected to do in order to accomplish the stated missions;
- labor agreements, which limit testing, certification, or written acknowledgments by workers, for instance, that a new rule was actually read and understood; and
- staffing or equipment problems, which encourage undue overtime, or "quick repair and use of equipment."

Any safety plans which assume that these things can simply "disappear" in the interests of safety must be considered naive. Therefore, part of our mission today must be to consider how much can realistically be done, and which obstacle/barriers it is absolutely vital to overcome to have effective safety action.

Acknowledgements

The funding of the University Research Program of the U.S. Department of Transportation for the development of the methodology reported is gratefully acknowledged, while recognizing that the responsibility for it is ours and not theirs. The significant role of Professor Edmund J. Cantilli and other faculty members at the Polytechnic is equally acknowledged.

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PROBLEMS IN ESTIMATING THE POTENTIAL FOR TRANSPORTATION CATASTROPHES

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Abstract

Less than 1% of all accidents are classified as catastrophes by the arbitrary definition of either 10 fatalities, 30 injuries, or $3 million in property damage, yet nearly all media and public attention focuses on such incidents. On the other hand, it is recognized that the potential for large, but rare transportation accidents exists. Should these be taken into account in transportation safety? If so, a number of questions must be addressed which are outlined in this paper.

The paper will focus on the problems of estimating such risks and provide a framework for identifying them. Problems in the data bases for estimating rare events are covered, and subsequently several possible schemes for identifying risk-prone systems are provided. They are presented as possible approaches for consideration and not as developed methodologies.

Introduction

The potential for transportation catastrophes, involving the transport of hazardous materials, is well recognized and considerable resources are focused on both prevention and mitigation. Depending upon the definition of a catastrophe,[1] less than 1% of all accidental deaths are associated with catastrophes. The attention given to these incidents by the media and the public is far greater than would be warranted by consideration of the raw numerical statistics alone. Since such public anxieties influence policy, such concerns cannot be ignored; moreover, the concerns may be justified. This leads to a fundamental policy question related to the transport of hazardous materials: Are the risks increasing? The question may be partitioned more meaningfully by addressing the sub-question: Are the risks increasing disproportionately to the volume of traffic? Is the potential for catastrophes increasing?

There are major difficulties in addressing these questions in terms of historical data. In general, catastrophes are rare events; that is, they do not happen often enough or the conditions under which such occurrences can occur are constantly changing, so that historical trends can be misleading.

If answers can be found in a general sense, a number of sub-issues can be addressed:

- How may such risks be estimated?
- How big a problem are these potential risks?
- What is the proper mix of prevention, mitigation, and disaster relief strategies?
- What resources should be devoted to research in respect to the scope of the problem?
- Who should address such risks?
- Under what conditions are such risks acceptable?

The objective of this paper is to provide a framework in terms of a meaningful measure of catastrophic potential for addressing general answers to the initial questions, so that some of the questions and sub-issues can be put into perspective.

Historical Data

Since catastrophes are hoped to be rare events, historical data should be expected to be sparse; in most instances this is borne out. Figure 1, reproduced from Chemical and Engineering News,[2] indicates that the number of incidents involving hazardous materials is on the increase. However, if one normalized these for the volume of traffic in each case, depending on the normalizing parameter, for example ten miles, many of these increases disappear. For example, the total vehicle miles of truck travel on urban, main, and local rural roads increased at about 6% per year from 1968 to 1978.[3]

The statistics just do not show major changes in the rate of catastrophes from hazardous materials. Based upon historical data alone, one must come to the conclusion that the problem is under control. However, nearly all people who are participants in the industry have the intuitive feeling that the conditions for large disasters from hazardous materials accidents are getting worse, namely, the potential for catastrophe is increasing. Which is correct? Data or intuition?

It may well be that we have been looking at the wrong data or the real problem is masked by the rarity of catastrophic events and by other factors. When the events are not rare, it becomes evident that large accidents cause more problems than small incidents. The number and volume of tank barge spills is a case in point. Table 1 shows the number and volume of tank barge spills in eight port systems over a five-year period. Six spills representing only about 2% of the number of incidents, resulted in 66% of total volume spilled. Large accidents predominate although they happen less frequently.

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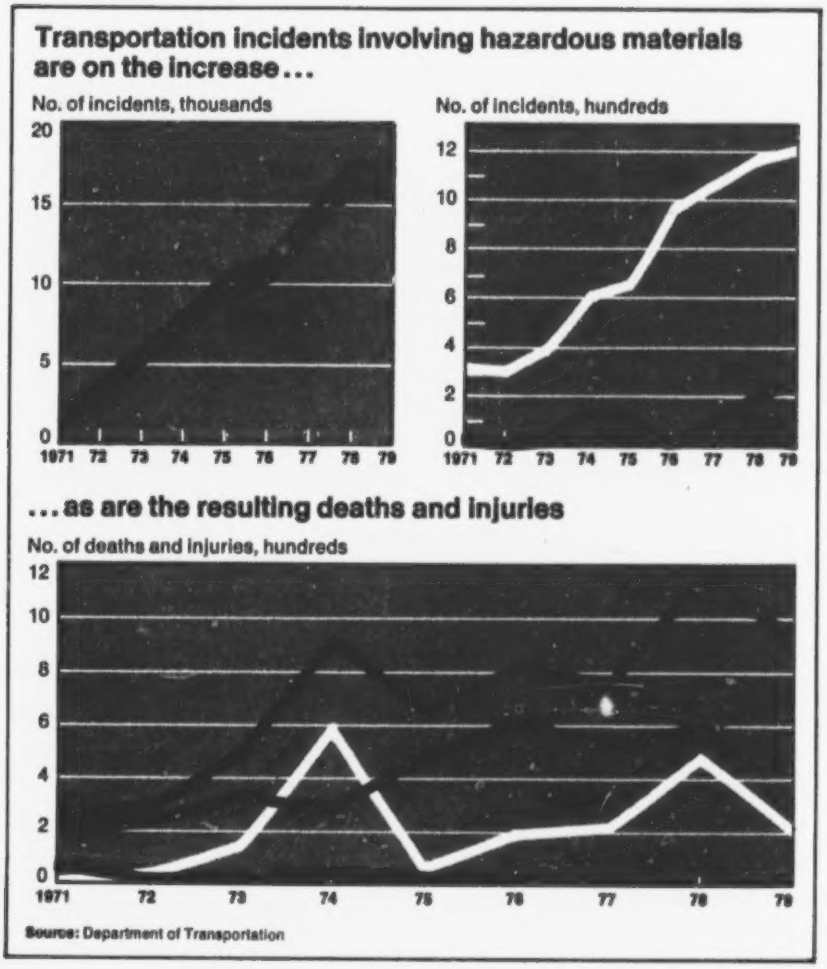
FIGURE 1



Graphs reprinted with permission of Chemical & Engineering News

If we are measuring the wrong data, what should we be measuring? Several possibilities exist, two of which are explored here: sources of hazard and breakdown of redundant safety margins.

Sources of Hazard

Source of transportation hazards as opposed to causes of accidents occur because of three conditions:

1. stored potential energy,
2. kinetic energy of motion, and
3. toxic materials.

TABLE 1

NUMBER AND VOLUME OF TANK BARGE SPILLS IN EIGHT PORT SYSTEMS (1973-1977)
(FOR SPILLS ≥ 2.4 BARRELS)

Spill Size (Barrels)	Number of Spills	Percent of Total	Volume of Spills (Barrels)	Percent of Total
2.4 - 10	211	63.2	1,029	1.8
10.1 - 50	79	23.6	1,885	3.3
50.1 - 100	12	3.6	915	1.6
100.1 - 200	11	3.3	1,677	3.0
200.1 - 2,000	15	4.5	13,716	24.3
> 2,000	6	1.8	37,259	66.0
TOTAL	334	100	56,481	100

SOURCE: PIRS, U.S. Coast Guard, 1978.

These are shown in Table 2 along with several examples of each. The first case of stored potential energy is fairly obvious in terms of fuels and explosive chemicals. From 1971-1978, 65% of all fatalities involving hazardous material transport resulted from incidents involving gasoline or liquid propane gas,[4] and 9% from chlorine. In the latter case, chlorine is both toxic and explosive. This leads one to believe that combinations of the three conditions lead to even greater potential for catastrophes, as shown in Figure 2. Since transportation systems involve kinetic energy by its very purpose, that is moving materials, such systems accentuate the hazard potential. When all three are combined in an action such as transporting obsolete nerve gas explosive shells, the hazards are potentially greater.

Even if the hazard potential exists, the magnitude of the potential catastrophe depends upon the possible impact on people, property, and the environment. Table 3 lists some of the recipients of risk in terms of these classifications.

The objective of a safety program would obviously be to minimize the conditions for hazards and to isolate their occurrence from risk recipients.

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Essentially, a simplistic analysis of this nature results in a very simplistic solution: do not ship large volumes of hazardous materials through routes which expose people, property, or the environment. Of course, such a solution would, in many cases, severely affect our economy and our standard of living. Certainly, minimizing exposure to hazardous material accidents is always important when such exposure is easily avoided. However, such approaches do not take into account the many safety systems that can be effective in preventing and mitigating such accidents. Unfortunately, the effect of safety systems cannot be measured very well on the basis of existing data gathering systems.

TABLE 2

SOURCE OF TRANSPORTATION HAZARDS
(As Opposed to Cause)

STORED POTENTIAL ENERGY	KINETIC ENERGY	TOXIC MATERIALS
EXPLOSIVE CHEMICALS	**MOMENTUM**	**GASES**
Acetyle Peroxide	Vehicle	Chlorine
Chlorine	Loading Machinery	Diborane
Ether	Cargo Shift	Flourine
Picric Acid		Hydrogen Sulfide
FUELS	**CENTER OF GRAVITY**	**LIQUIDS**
LNG	Changes	Tetraethyl Lead
Propane	Stability	Sulfuric Acid
Gasoline		Nitrobenzene
Crude Oil		Hydrogen Cyanide
	FALLING OBJECTS	
	Cranes	
FLAMMABLES	Stacked Cargo	**SOLIDS**
Acetone (F.L.)		Phenol
Benzene (F.L.)		Potassium Cyanide
Flourine (F.G.)	**CLOSE-ROOM MANEUVERING**	
Phosphorous (F.S.)	Docking	
	Passing	**RADIOACTIVE MATERIALS**
	Harbors	
	Rivers	

In the maritime industry, to improve safety for those vessels involved in hazardous cargo shipment, the Coast Guard has introduced many new regulations, navigational aids, and inspection systems. It has not been possible to measure how these safety innovations have actually affected safety; that is, the data show neither dramatic improvement nor deterioration in accidents involving the transport of hazardous materials.

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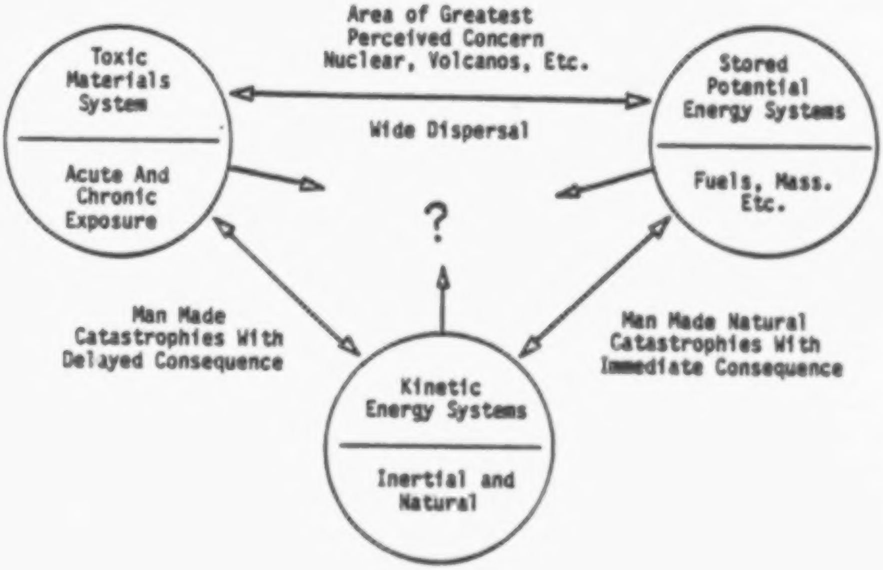
FIGURE 2

SYSTEMS PRONE TO CATASTROPHIC EVENTS


Area of Greatest
Perceived Concern
Nuclear, Volcanos, Etc.
Toxic
Materials
System
Acute And
Chronic
Exposure
Stored
Potential
Energy Systems
Fuels, Mass.
Etc.
Wide Dispersal
?
Man Made
Catastrophies With
Delayed Consequence
Man Made Natural
Catastrophies With
Immediate Consequence
Kinetic
Energy Systems
Inertial and
Natural

Redundancy and Margins of Safety

Means to provide a more meaningful evaluation of transportation safety are postulated here, namely, that safety is a function of multiple, redundant systems, each with a margin for error intrinsic to the system. Moreover, accidents only occur when the margin of error in each of the redundant systems is overcome simultaneously for whatever reasons. For example, a near miss or a collision of passing vehicles is only a margin of distance or lack of such margin.

As long as margins of error (or safety) are not exceeded, accidents do not occur. What is not known is how much margin of error and redundancy exists and whether these margins are being reduced. For example, as traffic builds up to capacity in a port, redundant systems of traffic control, separation and maneuvering room during passage, and ship-to-ship communications all work to prevent collisions. Once capacity is exceeded, all margins for error may disappear and a steep rise in collisions and rammings must be expected. The change in hazard potential is abrupt and non-linear, once redundancy and safety margins are used up. The impending conditions may be well-masked up to the point of exhaustion.

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TABLE 3

RISK RECIPIENTS
(Hazardous Material and Waste Accidents)

PEOPLE	PROPERTY AND ASSETS	ENVIRONMENT
GENERAL PUBLIC Dwelling in Proximity to Routes Passengers Bystanders Random and Systematic Contact	**VEHICLE** Loss-Damage Out-of-Service **CARGO** Loss-Damage	**ECOLOGICAL** Temporary Permanent Damage Local/Global **WILDLIFE** Short Term Loss Extinction
OCCUPATIONAL Hazardous Material Workers General Transportation Workers Safety, Rescue and Recovery Workers (Death, Injury, Relocation Anxiety and Discomfort)	**FACILITIES** Loss-Damage Out-of-Service **PROPERTY** Loss-Damage Liability **RESPONSE COSTS** Material Man-Hours Resources Equipment Evacuation Theft-Looting	**CLEANUP COSTS** Financial Damage by Cleanup **LOSS OF USE OF LAND** Radiological Toxins Toxicity Level

An analogy using control theory parlance may be useful. The measurement difficulty here is similar to that of trying to measure the parameters of a high gain control system with negative feedback. The objective is to measure the open-loop gain and system transfer function without disconnecting the feedback loop or exceeding the gain of the system. The feedback masks the parameters to be measured. Thus, any measures will not be very precise, and a resultant set of indices will be more descriptive than normative.

It should be possible to develop some understanding of the effect of redundant safety systems and margins of safety such that the degree of redundancy and margins can be ascertained on either an absolute or relative basis. In the first case, an absolute measure of redundancy and safety margins can provide insight as to how far one is from potential catastrophe. In a relative sense, alternate systems can be evaluated as to their degree of safety, allowing attention to focus on those with the least margins. Alternatively, the impact of alternate safety approaches can be evaluated as to how much redundancy and how many safety margins they add to a system, for example, double hulls in barges.

I do not know of any attempts to develop such measures, but I have a few ideas as to how they may be approached. First, fault-free and event-free techniques may be useful in determining the critical conditions for which redundancy and safety margins are needed. Next, the types of redundant systems and safety margins for each must be identified. The best that can be hoped for might be figures of merit based upon these principles. The next section outlines some preliminary thinking in regard to the development of such indices.

Indices for Risk in Terms of Safety Margins

The concept of indices used here embodies more than the idea of a single variable on a continuous scale. Multiple indices using a variety of nominal, ordinal, and interval scales are contemplated. Perhaps they could be better referred to as appraisal criteria.

The first requirement of indices for evaluating the risk of catastrophes through analysis of redundancy and margins of safety is that it be related to the magnitude of the risk. Thus, the first requirement is to identify the potential catastrophe and its magnitude. Three questions immediately arise:

1. Should an average or worst-case or even worst-case imaginable catastrophe be used as a reference?
2. Should the magnitude be measured in fatalities, morbidity, property damage, environmental damage and direct recovery costs?
3. Should a single weighted measure be used or a multiple index which evaluates each case separately?

The second requirement is to identify the systems that provide safety redundancy and the margin of safety each system provides under specific conditions. The redundant systems can be preventive, operationa. or mitigative as illustrated in Table 4.

The cases shown here are only to illustrate the wide variety of systems that exist which provide margins of safety. In any particular case a multiplicity of such systems are operative, providing redundancy. In each case the margins of safety provided by each system must be identified and quantified in some manner. Perhaps it is not the margin of safety that should be ascertained but the conditions that reduce the margin of safety by a given level. For example, a system requiring visible markers will not be of use during heavy fog.

The combinations of the many systems that protect against a given catastrophe provide redundant protection, at least in cases where they are used properly. The objective in providing a figure of merit is to find those conditions when redundant systems fail, due to common mode failures, or where systems aimed at providing protection for the same hazard lose their effectiveness under specific conditions. Investigation of accident cause data can provide insight on what has resulted in accidents; but since most of these systems report incidences over a certain degree of seriousness, a major look at data on ordinary and repetitive system failures and "near-misses" is evidently lacking. In cases where an accident investigation tends to be punitive in purpose or adversarial in nature, the identification of the actual causes can be not only inhibited but purposefully masked.

TABLE 4

SAFETY SYSTEMS THAT PROVIDE MARGINS OF SAFETY
(for illustration only)

PREVENTION OF ACCIDENTS	OPERATIONAL CONTROL	MITIGATION
DESIGN - Vessel/Vehicle/Airframe	TRAFFIC	RESPONSE
Design Margins-Double Hull Barges	Procedures	Rescue
Redundant Systems - Multiple Steering	NAVAID'S	Fire Control
Safety Equipment	Markers	Material Containment
	Radar	Shelter
		Evacuation
DESIGN - Traffic Control	OPERATOR PERFORMANCE	PROTECTION
Equipment	Experience	Shelter
Procedures	Training	Policing
Maneuvering Space	Redundancy of Personnel	Recovery
NAVAID'S	Communication	Insurance
	Comprehension	Disaster Relief
	Fatigue/Stress	Salvage
	Human Factors	Cleanup
MAINTENANCE	OPERATIONAL CONDITIONS	
Preventive	Weather	
Routine	Traffic	
Training	Calculated Risk Situation	
Spare Inventory		

Two kinds of analyses must be made and somehow merged. The first type of analysis involves the systematic identification of safety margins for a particular mode of travel for a specific or at least typical route. This involves identification of both time and spatial relations as well as human performance variations. Layout of route activities from pre-departure planning and scheduling through final disposition of delivered material provides one method of examining the effect of redundant systems and short-fall situations. To some extent this is a form of fault-free and event-free analysis, but it is not used to determine the impact of a fault or an event. Rather it is aimed at evaluating the multiplicity of systems that are operating to provide measures of safety margins under varying conditions. This coupled with frequency of occurrence data for simple events and failures can provide a first cut measure of the level of redundancy for each situation. In addition, operator task analyses, energy analysis for specific routes, and failure mode analyses can be brought into the picture.

The second kind of analysis must look at the overall system. Stress conditions such as limited traffic capacity, vulnerable exposure conditions, and adverse weather conditions are one aspect. Another aspect involves a means for comparing the margins of safety in alternate modes of transportation. Fixed assets versus mobile assets must be compared on some reasonable basis, as to how each contributes to either accident cause or to providing safety margins. Total system energy analysis coupled with system failure mode and effects analyses might prove effective in this context.

When both kinds of analyses are undertaken, a cross-walk must be taken back and forth between them, since a problem in one kind of analysis can help identify problems and possibly solutions in the other analysis. Moreover, both analyses have to be merged into an overall system to provide useful indices.

Thus, an index requires consideration of the magnitude of risk and the exposure pathways causing the risk, identification of redundant systems and the margins of safety they provide for specific conditions, and identification of the causes or loss of safety margin, individually and for the overall system and some idea of the frequency of such causative events.

Some Concluding Remarks

It is evident that the rarity of catastrophes makes reliance on historic data for projection of future disasters nebulous at best. In the absence of good predictive indices, intuition is all we have to go on. The very things we are trying to measure, that is the probability of catastrophic system failure, is effectively masked by the many precautions and safety systems designed to avert such disasters. There is not even a good measure of how effective, in terms of both risk reduction and the cost effectiveness of risk reduction, such precautions and safety systems are.

It is evident that better measures are needed. If and when suitable measures are developed, they can be used to evaluate, for example, the effectiveness and cost of alternative safety systems for a given mode of transportation or across modes. Some of the measures might be used to identify systems which are particularly vulnerable to catastrophe and the need to bring them into acceptable levels in comparison with general society practice. Such measures can also be used to determine new and effective approaches to safety. No one set of measures can accomplish all these objectives since some cases only require relative measures, while others require absolute measures.

Simplistic approaches are liable to provide simplistic answers which may well be deceptive. Dealing only with sources of hazards is an example. The concept of addressing and measuring system redundancy and the margins of safety derived is an attractive approach and certainly not simplistic. The degree to which useful measures can be developed is still a question, especially in terms of development costs and suitability in all the applications envisioned. It will take some major effort to answer these questions.

In summary, I can say that the old methods tell us little, and often provide deceptive results. Clues are available on how better measures can be found, but a great deal of effort is required to develop the measures and to determine their reliability and usefulness.

NOTES

1. One definition of a catastrophe is 10 lives lost, 30 injuries, or $3 million or any combination of these. It is admittedly arbitrary, but provides a reference.
2. Chemical and Engineering News, 24 November 1980, p. 21.
3. National Transportation Statistics, September 1980, p. 23.
4. Op. cit., Chemical and Engineering News.

SOME THOUGHTS ON DETERMINING THE BOTTOM LINE FOR ACCIDENT REDUCTION IN TWO AREAS

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Abstract

The paper uses two areas of transportation safety as examples of the problem of determining cost-effectiveness of safety programs. In one area, rail-highway grade-crossing safety, fatalities have been greatly reduced in the decade of the 1970s. The safety program has been very successful, but now there are those who say the cost has been too great relative to the numbers "saved," and future programs may be endangered. In the other area, hazardous materials transportation accidents/incidents, fatalities are even fewer, but the trend is to spend ever increasing amounts on safety programs.

The paper asks several questions: How should cost-effectiveness be evaluated in these two areas? When is it appropriate to say the level of deaths has reached a point where a program should be terminated? Are traditional effectiveness measures appropriate in these areas?

The paper uses a critique of the massive highway safety program of the 1960s as a base for exploring appropriate philosophy to approach these issues. The case is made that too much concern was given to specific accident causes and specific system components. Safety was too often treated as an end in itself rather than a by-product of mobility. The point is made that with a given level of mobility desired, there is an associated cost and risk. When mobility is the paramount issue, then it is appropriate to develop a risk, mobility, and resource relationship within specific goals and constraints.

The author relates the above philosophy to rail-highway grade-crossing safety and hazardous materials transportation safety. Rail-highway grade-crossing accidents and hazardous materials incidents are rare events. It is extremely difficult to collect sufficient data to develop traditional effectiveness measures. This fact is particularly true in the areas of hazardous materials and vehicle/train collision if effectiveness is measured in terms of casualties or fatalities.

But these are high-risk situations and should not be ignored because in both areas, the possibility of a catastrophic event exists. Since traditional risk analysis takes into account the product of the probability of an occurrence and the consequences, "catastrophic potential" is taken into account. In these and similar areas, it is concluded that risk analysis methodology should be perfected and utilized. When the level of risk is acceptable for a desired level of mobility in a system, then, and only then, can it be determined what level of expenditures is appropriate or if an "acceptable" threshold of accident reduction has been reached.

The paper concludes with a brief synopsis of the state of the art of risk analysis models, insofar as their current utility in the two areas discussed.

Introduction

This paper addresses the question "How much safety is reasonable?" It will likely generate more questions than it will answer. The author does not claim to know the answer. After twenty years of study, research, and experience, the answer--if there is one--has become less clear and more perplexing than ever in recent years.

In the mid-60s, when over 50,000 persons were being killed annually on United States highways, "50,000" seemed to be the magic number that stirred the Nation's consciousness. Suddenly, it became a national problem that seemingly could be solved by allocating vast sums of money to programs aimed at its solution.

One fact that is hard for some to understand is that before 1966, less than $500,000 was spent annually on highway safety to protect 100,000,000 highway vehicles, while $60,000,000 was being spent in air search and rescue operations to protect 130,000 planes.[1] Who, in those days immediately following 1966, questioned whether casualties could be reduced, how much reduction was feasible, and at what cost or how much should be spent per expected accident or fatality reduction? Only in recent years has honest concern over these questions surfaced in the form of emphasis on project and program evaluation and various measures of effectiveness.

Two areas of transportation safety will be examined in the above context. One is the problem of safety at rail-highway at-grade crossings and hazardous materials transportation. The first problem has been with us since the mid-nineteenth century.[2] The latter is relatively new.

In the late 1960s it became clear that accident reduction at rail-highway at-grade crossings was possible with concentrated effort. In the decade of the 70s hundreds of millions of dollars were directed by means of categorical grants toward grade-crossing safety projects.[3] It was a very successful program.

The record shows that there has been a fairly steady decline in crossing accidents from an average of 1,395 per year from 1967 through 1971 to 733 in 1979 and 704 in 1980. That is a 50% decrease in fatalities. There also has been a 14% decrease in motor vehicle involved crossing accidents from 10,925 in 1975 to 9,435 in 1980. This has occurred in spite of a 40% increase in exposure due to increased train and motor vehicle traffic volume (4,5).

The grade crossing safety categorical funded program has continued to reduce crossing accidents and fatalities in spite of increased exposure. Some industry representatives believe strongly that it should be continued, particularly so as to permit selective improvement of off-system crossings (4).

In recent years, some government agencies and professionals are beginning to wonder if we have reached the "bottom line" of accident reduction at grade crossings and are questioning the cost of further reductions.[4]

A recent General Accounting Office (GAO) report by the Comptroller General, Rail Crossing Safety at What Price? (CED-78-83, April 25, 1978), questioned the current level of funds being spent on grade-crossing programs. The GAO reviewed this topic because it was argued that the percentage of safety money expended was out of proportion to the percentage of all accidents that were grade-crossing related.

Railroad officials and other professionals are deeply concerned about eliminating designated programs for grade crossings.[5] The Association of American Railroads (AAR) contends, however, that safety goals have not yet been met and that shifting traffic patterns on the railroads are creating new problems.

It appears that the heart of the dilemma is: would the fatality rate hold at 700 deaths per year or would it "skyrocket" if the program is dropped? In reality, it is extremely difficult to evaluate many safety benefits at rail-highway grade-crossings.

The main thesis of this paper is that to simply look at the current death rate as an indicator that funding should be cut back is inappropriate. Also, the argument that the program is not justified because funds spent are out of proportion to current accidents is a poor one. These two points will be developed and illustrated in later sections.

Hazardous Materials. Perhaps because of events in recent years such as in Waverly, Tennessee, (16 killed, 45 injured) and Youngstown, Florida, (8 killed, 114 injured) where train derailments had catastrophic results, it seems that the nation has "discovered" a "new" transportation problem of great magnitude.

The transportation of hazardous materials, "a substance or material in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce,"* is an essential activity in the twentieth century. All sectors of the economy are highly dependent on this activity because the impedance of these materials becomes prohibitive unless one can accept the return to a primitive civilization in which the hazards to life and health would likely exceed the dangers inherent in their transportation of hazardous materials.

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*As defined in the Hazardous Materials Transportation Act (HMTA), 49 USC 1801, et.seq.

The transport of hazardous materials poses a problem because, uncontrolled, these materials can be harmful. The number of these materials is in excess of 18,000, with more being entered into commerce every day. The American Automobile Association estimates that two billion tons of hazardous materials are transported by highway vehicles annually, and the American Association of Railroads estimates over a million carloads--about 80 million tons--are transported by rail annually.[6]

The Problem in "Perspective"

The great concern over the dangers, real and perceived, as well as the strong emotional response to the mere mention of nuclear materials-- would lead one to believe that this is a new problem that had sprung up overnight. In reality, professionals, particularly railroad officials, have been dealing with these problems for many years.

One cannot help but recall 1966 when a "tremendous highway problem" seemingly developed overnight. Now, there is a "hazardous materials transportation" problem. That is not to say the problem is not real--it is. That is not to say we should not be concerned--we should. But our concern should be rational, not laced with decisions (and costly programs) clouded by strong emotion or near panic. Lessons should have been learned from the period beginning in 1966 when great chunks of our resources were thrown into the fight against highway fatalities. Some battles were won; but in retrospect, can we say we won the war? Although accident rates are generally down (a meaningless statistic to the general public), actual numbers of fatalities are not down much lower than in 1966. It can be argued that with massive increases in exposure due to increased traffic on the highways, holding the number steady is actually a victory. The author contends that this is negative thinking and constitutes a "hollow victory." There is still no consensus on what specific programs were (or are) effective and how effective, quantitatively, or in fact how effectiveness should be measured.

In his book, The Highway Risk Problem,[1] Baker looks critically at these issues. He believes his main points are valid today and should be studied in depth and contemplated and extended to current problems, such as the hazardous materials problem.

Next, let's try to put the highway safety problem, the rail-highway grade-crossing problem and the hazardous materials transportation problem in some sort of perspective, or at least ponder some figures.

In 1979, the highway death toll was about 50,000 deaths that prompted a variety of responses back in 1966; this issue has definitely cooled. In 1979 there were about 12,000 accidents and 733 deaths attributed to vehicle/train crashes at grade crossings, and some think this issue is dead or dying. In 1979 there were 17,524 hazardous materials transportation incidents by all* modes which resulted in *46* deaths and *941* injuries. Hazardous materials transport is one of the most discussed transportation issues today.

A breakdown by rail and truck shows that in 1979 there were 15,978 highway hazardous materials incidents versus 1,215 rail incidents, 20 highway-related deaths versus 26 rail-related, and 697 highway-related injuries versus 228 rail-related. Perhaps even more interesting is that in 1979 there were 1,970 gas pipeline failures resulting in 45 fatalities and 406 injuries and 249 liquid pipeline failures with four fatalities and thirteen injuries. Yet, with all the "headlines" lately, one would think rail was the only problem mode.

The above figures also can be perplexing insofar as the category of materials is concerned. During the period 1971 to 1975, over 51% of the hazardous materials incidents and most of the deaths involved flammable liquid, primarily gasoline. Incidents involving gasoline are so routinely accepted by the general public that some do not even consider gasoline a hazardous material. Only 0.45% of the incidents (144 total) involved nuclear materials, most of which involved minor or suspected contamination of container or vehicle, but it is these shipments that are about to be highly restricted by selected routing.[6]

In light of the above facts, the real issue then appears to be perceived danger or, more specifically, perceived involuntary risk to which the public envisions itself being subjected. For example:

> A news story about inadequacies in the water supply at Potomac Yard in northern Virginia became a two-week sensation when they related to *possible* hazardous materials accidents. The local governing body had to take *emergency action* to do something about a condition that (had) existed for *74 years*.[6]
> (emphasis added)

This paper is not suggesting that this is not a valid issue, but it is leading to the conclusion that traditional cost-benefit or cost-effectiveness measures are inappropriate for events as rare as a vehicle/train accident at a grade crossing or a major hazardous materials incident. This is especially true for catastrophic events.

There is a question whether the public is ready to accept risk analysis--to realize that "living" is a risk. The public needs to understand and accept the fact that they may be at no greater risk from a radioactive shipment than from a vacation in Denver. This fact and other comparisons can be deduced from Tables 1 and 2.

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*exclusive of pipeline

One can note other "perplexing" observations in these tables. In Table 1 the individual risk of railway accidents* is about one-half that of airplane crashes, and gasoline tank truck accidents with the worst (most frequent and most deadly in fatalities per year) hazardous materials accident records, are at the bottom of the list. In Table 2, where various radioactive materials are compared to gasoline, it can be seen that the radioactives present miniscule risk by comparison. However, where is the public concern? Where is the money spent?

Is the amount of safety money spent in these areas any less out of proportion than rail-highway grade crossing accidents?

A spent fuel ("yellow cake") incident, a relatively small spill, occurred in Wichita, Kansas, about two years ago. The local and State experts believed the spill was of small risk to anyone; however, following existing regulations, the clean-up cost exceeded $2,000,000. Since this incident, there have been outcries by a "jittery" public to ban hazardous materials shipments in and through Wichita. (At what economic cost?)

How would one justify the ratios of resource expenditure in these areas by a traditional cost-effectiveness analysis?

Effectiveness - State of the Art**

It has been this author's experience that in both areas, rail-highway grade crossings and hazardous materials transportation, good data of the type necessary for a valid effectiveness evaluation are just not available.

Confusion exists over the definition of evaluation. It has been called "a rubber word that is stretched to mean whatever you want it to mean."[9]

A University of North Carolina report gave a clear description of evaluation:[10]

> Since evaluation is an ambiguous concept for most people, it is very important to explain exactly what the term means. Essentially, there are three types of evaluation:
>
> 1. Type I (Subjective, Clinical Assessment). This type of evaluation is reflected in the impressions of so-called "experts." It is usually devoid of numerical data and is necessarily filled with subjective feelings and opinions. In the field of highway safety, judges, police officers, and medical doctors frequently serve as expert evaluators.

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*Railway accidents in this table refers to vehicle-train collisions.

**Relative to grade crossing and hazardous materials studies.

2. Type II (Process Evaluation). This type of evaluation is numerical in nature but devoid of dependent variables to monitor. It is used to determine if (and to what degree) the treatments or manipulations advocated at the initiation of a program were carried out.

3. Type III (Outcome, Effectiveness Evaluation). This type of evaluation is characterized by the measurement of a dependent variable. When a program is instituted which is intended to influence one or more other variables, then measurement of changes in those other variables constitutes a Type III evaluation.

TABLE 1

COMPARISON OF GASOLINE TRANSPORTATION RISKS WITH INDIVIDUAL RISK FROM VARIOUS ACCIDENTS AND NATURAL DISASTERS (1977)
(Reference 7)

Accident Type	Total Fatalities	Individual Risk per Year
All Accidents	115,821	1 in 2,000
Motor Vehicle Accident	55,511	1 in 4,000
All Industrial Accidents	14,100	1 in 6,000
Falls	16,506	1 in 13,000
Drowning	7,152	1 in 29,000
Fires	6,503	1 in 32,000
Poisoning	5,335	1 in 40,000
Airplane Crashes	1,668	1 in 130,000
Railway Accidents	789	1 in 250,000
Lightning	160	1 in 2,000,000
Tornadoes	90	1 in 2,300,000
Gasoline Tank Truck Accidents	29	1 in 7,400,000

TABLE 2

RISKS OF SEVERAL HAZARDOUS MATERIAL TRANSPORTATION SYSTEMS IN THE 1980s
(Reference 8)

Material	Mode	Risk (Deaths per Year)
Gasoline	Truck	28
Plutonium Oxide	Truck	5×10^{-6}
	Rail	1×10^{-6}
	Air	7×10^{-5}
Uranium Hexaflouride	Truck	8×10^{-6}
	Rail	1×10^{-4}
Spent Fuel	Truck	4.5×10^{-5}

Because of a lack of, or the sparse nature of the data, only Types I and II are really applicable to grade-crossing and hazardous materials incidents. In grade crossings, diagnostic teams have been used. In hazardous materials, Delphi panels have been used frequently in recent research.[11, 12] Sometimes a surrogate variable from these areas is adaptable to Type III analysis.

Usually we are looking for small improvements. An excellent study to design a field experiment to test effectiveness of improved passive, advanced warning signs where accident reduction in the range of 2 to 5% was expected (based on previous head movement studies) gives great insight into the problem.

Passive crossings as a group have relatively low traffic volumes and very low expected accident rates per crossing (rare events). Thus, the experimental design had to be sensitive to relatively small accident rate reductions which would occur over a large percentage of grade crossings.

The conclusions were:[13]

1. The sample sizes necessary to detect the minimum percent accident reduction that would economically justify deployment of a new sign significantly exceed the population of available sites.
2. The estimated cost of conducting even the most cost-effective study designs would equal or exceed the approximate total cost of deploying a new sign on an as-needed basis over a seven-year period.
3. No study design is likely to reveal a statistically significant accident reduction, if in fact there was one.

If we cannot prove passive signs do any good, can we remove them all?

One of the best recent hazardous materials studies looked at highway transport risk and developed a methodology for minimum-risk highway routing.[12, 14]

The researchers discovered early that data were not available on hazardous material flows on highways (a fact decried in numerous studies), nor were there any good models that related highway geometric and safety features to predicting truck accidents. Incident data were used as a surrogate for flow data, assuming a good positive correlation, and Delphi panels of experts were used to determine the important highway variables that related to truck safety on the highways.

Risk Analysis

Let us look at some fundamental concepts of risk and risk analysis and some points brought out by Baker. (See Reference 1.)

In his book, Baker takes issue with the fact that the major thrust of the highway safety programs of the late 1960s was toward perfecting each transportation component:

> The objectives became distorted. Instead of focusing on saving lives, efforts were distracted into attempts to get better vehicles (or parts of vehicles); or better highways (or fewer obstacles or better traffic signs); or better drivers (or fewer drinking drivers or fewer "accident-prone" drivers); or better law enforcement and improved emergency medical services. Baker argued that mobility was required to meet national goals and that safety provided better mobility by reducing accidents. This principle led to examining the most effective way to produce results rather than the best way to improve components; that is, the goal was to reduce fatalities in highway transportation, not to improve highways, vehicles, or drivers.

Baker points out that his idea of approaching highway safety realistically will be considered fatalistic and cynical by some people.[1]

> ... the use of statistical or probability concepts in highway safety merely recognizes a practical problem; that is, for rare occurrences we cannot collect sufficient data to develop a complete understanding of how the many parts act together to produce a fatality.

Baker's concept of the accident problem relates to risk:[1]

> Reduction in risk can be more effectively treated than can the elimination of "causes."

Throughout the book Baker makes the point that safety must be tied to the mobility desired and to the risks and resources associated with this desired mobility.[1] A quote in Baker's book, made by former Secretary of Transportation Boyd at a Governor's Conference in Delaware (April 4, 1968), was used by Baker to illustrate his contention that highway safety policy has been misguided. This writer believes that it could very well apply to the hazardous materials transportation problem in general and to risk analysis in particular.

> The problem isn't so much that we have been going in the wrong direction. The problem is that we have been going in all directions, and we've begun running into each other and falling over each other.

Risk analysis methodology has been developed and is currently being improved upon in the area of hazardous materials. This approach has been followed because it was always apparent that rare events of catastrophic nature were involved, and adequate historical data were not available. This use started or was given impetus by nuclear plant location.

The state of the art of risk analysis has not yet reached a generally accepted or easily used product.[15] Lack of adequate data basis on flows and consequences is the major drawback.[16]

In the traditional risk analysis:
Risk = (Probability of Occurrence) x (Consequences of an Occurrence).

The public needs to have a better understanding of risk. If acceptance follows understanding, then the decisionmaker's use of risk analysis will be more productive. At this point, however, there is no general acceptance among the public or the decisionmakers.

An article in the Electric Power Research Institute Journal (EPRI) reported on a meeting of the journal's advisory council convened to explore the risks to environment and health from energy production. Chaucey Starr, EPRI Vice-Chairman, commented that, "Risk-benefit analysis is designed to guide the decisionmaker in the direction of the most beneficial choices for society."[17] He noted, further, that the United States balance between social goals and individual rights was continuously shifting, and a method to interpret consensus social values relating trade-offs between various social objectives is needed. Risk-benefit analysis is a method for dealing with those trade-offs in which risks are significant factors.

Starr stated:[17]

> The success of a society in achieving its goals is determined in part by the degree to which perceptions reflect reality. To the extent that perceptions lag behind reality, resource misallocations will result.

Cyril Comar, Director of EPRI's Environmental Assessment Department, offered the following general guidelines for putting the results of risk analysis into perspective:[17]

1. Eliminate any large risk that carries no benefit or is easily avoided.
2. Eliminate any large risk (about one in 10,000 per year or greater) that does not carry clearly overriding benefits.
3. Ignore for the time being any small risk (about one in 100,000 per year or less).
4. Actively study risks that fall between the above-cited limits with the view that the risk of any proposed action should be weighed against the risk of not taking that action.

In regard to technology and risk in general, Reider makes some good points.[18] Reider believes that new technologies tend to make living safer; even though a new technology may introduce a new risk, the new risk tends to lessen with maturity of the technology. There is great need for better risk analysis models.

"Risk Analyses" Applied to Rail-Highway Crossings At Grade

Hazard index (H.I.) formulae for determining relative hazard at rail-highway grade crossings have been available for several years. In a 1968 report Richards summarized eleven formulas, with varying degrees of complexity, for computing hazard "risk" at rail-highway grade crossings.[19] Bezkorovainy tested all eleven formulas on 180 at-grade crossings in Lincoln, Nebraska, and from the results of statistical analysis, he concluded that the rankings were not statistically different although actual H.I. numbers were significantly different.[20]

The 1973 Federal Aid Highway Act required States to prioritize grade crossings so that the "most dangerous" crossings received attention first. Hazard Index formulae, acceptable for relative rankings, were commonly used for this task.

With the advent of the national railroad-highway crossing inventory, data became available to develop and test better accident prediction models.[21] Probably the most sophisticated, a multiple regression model developed by Mangert for the USDOT, gives a hazard index that is a quantitative measure of risk in terms of accidents per year.

In an advance notice of proposed rulemaking (ANPRM--Federal Register/Vol. 45, No. 115, June 12, 1980) Federal Highway Administration, DOT proposed a quantitative procedure for selecting traffic control systems at railroad-highway crossings. The first step would be to calculate a hazard index or hazard level of the crossing in question in accidents per year. This value is then compared to a threshold value developed from a resource allocation procedure that produces an optimum mix of warning system types for a given level of funding. As an example, Table 3 uses threshold values calculated on the basis of reducing the hazard index to within a range of 0.08 to 0.12 deaths per year as a basis for recommending specific improvements. (The decisionmaker could use other values.)

The above methodology is presented here as an example of what the author considers a step in the right direction, i.e., toward "risk models." One could choose any level of accidents per year that is acceptable and plan accordingly. This concept needs to be further explored and refined.

"Risk-Analysis" Applied to Hazardous Materials Transportation

In the case of hazardous materials transportation, a risk analysis methodology is not yet standardized, credible, or usable. In a recent report (not yet published) the author reviewed close to one hundred reports, papers, and articles on risk analysis.[23] It was concluded that most were too theoretical and/or too complex for general use. Most models were built on sparse data or surrogate data because reliable hazardous materials flow data are not readily available, nor are the consequences of an incident easy to predict.

In a recent Transportation Research Board Circular (July 1980), the ten most critical issues in hazardous materials transportation are presented. Three of these are directly related to the thesis of this paper:

> Issue 7. A comprehensive data system for the flow of hazardous materials by quantity, general hazard class, route, and mode... .
>
> Issue 8. The state of the art for hazardous materials transportation cost-benefit-risk analysis methodology... .
>
> Issue 10. The understanding of the public about the relative safety of hazardous materials transportation... .[24]

Issue eight is clearly related. The point of the other two is this: without better data (Issue 7) cost-benefit-risk analysis will not evolve to be the powerful tool it could and should be, and without public understanding and acceptance of the results, application of any such model, although valid, can be a futile exercise when it comes to defending program cost allocation.

It is not easy to develop or define criteria for acceptable risk levels. As expressed in a recent paper on risk assessment:

> The problem of defining criteria for acceptable levels of risk for given hazardous activities in our contentious society has so far been insoluble, although investigations and proposals for the development of such criteria abound.

An important point is brought out later in this same paper:

> Any society must, at some point, deliberately decide how we ought to balance economic benefits and costs against possible harm or loss of life.

Summary and Conclusions

1. Effort must be made to further develop risk, mobility, and resource relationships associated with specific safety goals and constraints.

2. In the areas such as grade crossing and hazardous materials incidents, risk analysis methodology is the only appropriate effectiveness tool because the events are too rare and consequences too unpredictable for traditional cost-effectiveness methods.

TABLE 3

QUANTITATIVE PROCEDURE (ANPRM NO. 115)

Existing Traffic Control Device	Calculated Hazard Index (H)	Recommended Action or Improvement
Passive	0.08 to 0.12*	See note below
	0.12 to 0.15	Flashing lights
	0.15 to 0.23	Flashing lights or gates and flashing lights
	0.23 to 12.4	Gates and flashing lights
	12.4 to 18.5	Gates and flashing lights or grade separation
	greater than 18.5	Grade separation
Flashing lights	0.12 to 0.18*	See note below
	0.18 to 3.7	Gates and flashing lights
	3.7 to 5.6	Gates and flashing lights or grade separation
	greater than 5.6	Grade separation
Gates	1.32 to 1.98*	See note below
	greater than 1.98	Grade separation

*When the calculated hazard index falls within this range, the decision may be to do nothing, improve the existing traffic control system, install a different type of traffic control system, or make some other improvement at the crossing.

3. In areas such as rail-highway grade crossings and hazardous materials, potential risk is a more appropriate measure than historical accident records.

4. There is a need to develop risk models that:

   - have more credibility,
   - are easier to apply on a system-wide basis, and
   - are understood and accepted by a wide range of professionals.

5. To make it all worthwhile, the public must be convinced that accepting some level of risk is a natural part of life.

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CANADA'S COOPERATIVE ROAD SAFETY PROGRAM

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Abstract

Canada's Federal/Provincial Cooperative Road Safety Program (1974-1979) resulted in a drop of 33% in the fatality rate, more than double the goal of 15%. The program and the effect of the countermeasures initiated during the program are described.

The success of the first program prompted Canadian governments to establish a second five-year program with a goal of a 17% reduction in the fatality rate. To identify the second goal, the knowledge and experience of researchers were used effectively by officials and politicians in making practical decisions on the level of the goal and the program elements to support the goal.

The process of identifying national goals and establishing two five-year programs made extensive use of research results and countermeasure effectiveness information while involving senior officials and politicians in the policymaking activity. The result was a major reduction in traffic fatalities; however, what may be more important in the long term is the on-going commitment to highway safety in Canada and the new mechanism for monitoring the trends in fatalities, injuries, and safety programs.

Introduction

During the Federal/Provincial Road Safety Program of 1974-1979 the road fatality rate dropped 33%. The Canadian road safety leaders selected a five year goal of a 15% reduction in the fatality rate when they initiated the program in 1974.

This paper does not describe the program in detail, nor does it attempt to prove that the program reduced traffic deaths in Canada. What it will describe is a process of bringing together decisionmakers from 11 separate political jurisdictions through a goal setting exercise to make policy decisions on the implementation of major safety countermeasures.

The risks of setting arbitrary or unrealistic goals are significant and the concerns expressed, for example, by Campbell of the Highway Safety Research

Center at the University of North Carolina[1], are legitimate. However, the benefits of a well-thought-out goal setting exercise makes the effort worthwhile.

The success of the first five-year program resulted in a second goal and program and important changes in the road safety management structure in Canada.

North Atlantic Treaty Organization (NATO) Committee on the Challenges of Modern Society (CCMS)

In the spring of 1970, Canada agreed to participate in the NATO/CCMS Road Safety Pilot Study. The study included a number of projects on problems considered to have high potential payoffs. Canada became the lead country for the Alcohol and Highway Safety Project. Each project included the formulation of goals, operational plans, and programs to meet the goals.

As a result of Canada's involvement in the NATO/CCMS study, a number of Federal government departments met regularly to coordinate Canada's input into the road safety pilot study and other CCMS activities. The Federal and provincial experts on road safety also met periodically since a number of the projects dealt with subjects of direct concern to the provincial governments. The initiation of regular meetings of experts within Canada was an important product of the NATO/CCMS Pilot Study.

Upon conclusion of the Pilot Study, the International Resolution on Road Safety was adopted.[2] The resolution included the following goal: "Nations of the Alliance resolve to use their best efforts to prevent any increase in the annual number of traffic deaths for each class of road user on their road networks over the next five-year period...." During the discussions leading to the preparation of this resolution, a goal of a 15% reduction in the fatality rate (number killed/10^8 miles or kilometers) was proposed. This proposal was rejected for some of the very reasons goal setting is viewed with suspicion--not well developed, not specifically related to the needs of each country, and the probability of success was not known for each country.

The Canadian Road Safety Goal

Canadian officials preferred the specificity of the 15% goal and, therefore, they proposed a goal of a 15% reduction in the nation's road traffic fatality rate over five years. This resolution was formally announced by the ten Provincial Ministers and the Federal Minister of Transport, February 22, 1974.[3]

Based on travel projections, the Canadian goal was slightly more stringent than the NATO one. It was felt that the call for a reduction in the road safety toll was more in keeping with the prevalent feeling in Canada that the consequences of traffic accidents were excessive and must be reduced. The same goal stated in terms of fatalities would have called for a reduction too small to have had any impact on the public. Nevertheless, the indicator which prompted the Ministers to jointly announce the goal was the absolute number of fatalities. Traffic fatalities had increased from 5,080 in 1970, to 6,706 in

1973,[4] the largest three-year increase on record. While this increase was much greater than that experienced in the late 1960s, it was consistent with long-term trends in Canada and, therefore, could be considered likely to continue unless new programs were developed and put in place.

The fatality rate, which was the indicator referred to in the national goal, remained constant in 1971, 1972, and 1973, although up from 1970 (apparently an abnormally low year). The travel component of the fatality rate is calculated from fuel tax figures factored by an estimated vehicle fuel consumption rate in miles per gallon (Km. per litre). This consumption rate has not been adjusted since 1959. It is, therefore, reasonable to assume that the rate increased in the period 1971-1973 since fuel consumption per vehicle-kilometer increased in the early 1970s due to vehicle design changes.

The Canadian Program

The five-year program announced by government road safety officials included:[5]

- increased use of seat belts,
- enforceable laws governing driving while impaired by alcohol,
- removal of road hazards,
- vehicle standards for trucks and buses,
- improved vehicle inspections,
- extended driver education, and
- increased police presence.

The selection of these program priorities was based on expert judgment, the results of the NATO study, and existing priorities in the provinces. There were no commonly used safety performance indicators other than fatalities and fatality rates at this time. The adoption of the goal and the establishment of the program to meet the goal created an incentive to inventory road safety activities and develop performance indicators for the countermeasures included in the program. The program also brought about a major change in government structures relating to road safety. Almost all Canadian jurisdictions established safety program offices with senior officials responsible for coordination and management of the safety program. Annual Federal-Provincial meetings were initiated for the purpose of reviewing progress in meeting the goal, exchanging information on new programs implemented and proposed, and examining the effectiveness of new programs.

The Federal Government established a new division within the Road and Motor Vehicle Traffic Safety Branch. This division, the Road Safety Programs Division, was responsible for coordinating the Federal-Provincial program and for managing the Federal contribution to the program. The Division prepared an inventory of existing road safety programs, organized and administered Federal-Provincial meetings, developed performance indicators, monitored progress, and initiated Federal countermeasures and demonstration projects.

Effect of the Program

A number of new road safety initiatives followed the public announcement of the goal. It is impossible to determine which, if any, would have been taken without the incentive of the national goal. The large number of countermeasures introduced was unquestionably made possible by the Ministers' public commitment to reduce the fatality rate. Six of the major initiatives were:

1. Increased use of seat belts
    - mandatory seat belt use laws in four provinces with jurisdiction over 80% of all Canadian drivers (passed but not proclaimed in a fifth province)
    - two national public education campaigns
    - numerous provincial public education programs

2. Impaired driving laws
    - Criminal Code Amendment to allow mandatory roadside screening tests and an easing of the justification needed to stop drivers for a test
    - national public education campaign to make the public aware of Criminal Code changes
    - new enforcement programs - Check Stop,[6] RIDE,[7] Counterattack[8]

3. Road hazards removal
    - development of a model[9] for setting priorities in roadside hazard removal and a manual[10] for the identification and treatment of roadside hazards
    - production of a manual[11] for the identification and treatment of hazards on minor roads
    - increased funds for the removal of roadside hazards

4. Vehicle safety standards for commercial vehicles
    - air brake standard for commercial vehicles
    - window retention for buses
    - a series of standards for school buses including body strength and seats

5. Improved vehicle inspections

   - new program introduced in Saskatchewan
   - major changes and expansion in Quebec

6. Extended driver education

   - development of a motorcycle training curriculum[12]
   - cooperative, Federal Government/Canada Safety Council, program to increase the availability of motorcycle training in all parts of Canada
   - development of an advanced driver training course[13]
   - school bus driver training programs were developed and introduced in Quebec, Saskatchewan and Alberta

Performance indicators were adopted or developed for many of these countermeasures.

Seat belt use - percentage wearing (measured by roadside observation).

Impaired driving - percentage of late night drivers impaired (roadside survey).

Removal of roadside hazards - percentage of fatal accidents involving fixed objects.

Vehicle safety standards - crash-worthiness - proportion killed of all drivers in accidents (driver fatalities/drivers involved).

Increased police presence - charges laid, for example, impaired driving charges.

In addition to these indicators which are directly related to program initiatives, the more traditional, "bottom line" indicators of fatalities, injuries and fatality rates were also used to measure the overall impact on the national program. Table 1 shows the changes in program indicators through the five-year period of the national program.

Program Effectiveness

By the end of the five-year program (December 31, 1978), the annual number of fatalities had dropped to 5,200 from 6,700 in 1973 and the fatality rate was 33% lower at 2.8 deaths per 100 million vehicle kilometers. How much of this reduction can be attributed to the five-year program and how much resulted from energy related changes in driving and safety countermeasures that would have been adopted in any event is impossible to estimate. In Canada the effect of the change in gasoline availability and price was less significant than in most Western countries. There was no shortage of gas for cars, and price increases were not exceptionally high in relation to other cost increases due to inflation. Annual travel in Canada continued to increase through the 1970s but at the slightly slower rate of 4% per year.

The effect of reduced speed limits which were credited with bringing about significant savings in fatalities in the United States was not as important in Canada. There was no national speed limit reduction although some provinces reduced the speed limit on primary highways in a selective manner.

The Second Program

The success of the first five-year program prompted the Federal and Provincial governments to adopt a second five-year program and a new goal of a further reduction of 17% in the fatality rate. The selection of this goal was more systematic than the selection of the first goal.

Federal and Provincial officials responsible for road safety programs were asked to forecast which new countermeasures were most likely to be implemented in the following five years. They were provided with information on the causes of accidents, a list of countermeasures in use, and the effectiveness of each based on the best information available. This process ensured that a realistic package of countermeasures would be included in the proposed program. Researchers are not normally able to fully assess the social and political factors that play a large role in the selection of government programs. By including the program administrators in the early stages of the exercise, these factors are given appropriate prominence.

From the forecasts provided by program officials, researchers in the Road and Motor Vehicle Traffic Safety Branch of Transport Canada prepared a short list of countermeasures. Based on research and effectiveness information they estimated the maximum number of fatalities and injuries that could be affected by the measure, and combined these estimates with reasonable predictions of the efficacy of each measure to produce an estimate of the potential impact of each one. Table 2 summarizes the results of this exercise. It should be noted that the Ministers had adopted a goal of 80% seat belt use prior to the start of the second program; this goal was the key to establishing the overall goal for the second five-year program. The impact of attaining 80% seat belt use by 1983 is shown in Figure 1.

To permit the officials to identify a goal for consideration by the Ministers, six scenarios were prepared as shown below.

I. Modest Increase in Seat Belt Usage Rate
II. Modest Increase in Seat Belt Usage Rate Plus Selected Additional Countermeasures
III. National Seat Belt Usage Rate of 80%
IV. 80% Seat Belt Usage Rate Plus Selected Additional Countermeasures
V. Double Traffic Law Enforcement
VI. Construction of Canadian Freeway Network

These scenarios were selected because they produced significant reduction targets and included all of the countermeasures suggested by provincial officials. Two scenarios, the doubling of traffic law enforcement officers and the construction of a freeway-class interprovincial highway network, were not considered feasible but were included for illustrative purposes. Estimates of the effect of each scenario were prepared based on a breakdown of fatalities as shown in Figure 2. The impact of each scenario is shown in Figures 3 through 8. Figure 9 summarizes the apparent costs and benefits of each scenario. The final decision, therefore, was not made solely on optimism and popularity but also with full knowledge of the probable costs.

Based on this material, Scenario IV, 80% seat belt use, plus a reasonable package of other countermeasures, was selected as the new five-year program. This program was estimated to achieve a 17% reduction in the fatality rate. This recommendation was accepted by the Ministers. The goal was described as follows: the fatality rate will be reduced 17% and in any event there should be no increase in traffic deaths between 1978 and 1983. The program to attain this goal was:

- 80% use of seat belts,
- decrease the extent of impaired driving,
- promote traffic safety education in the schools,
- encourage more effective allocation of traffic law enforcement resources,
- continue roadway improvements, and
- promote pedestrian safety.

The resources for the Safety Programs Division which coordinated and stimulated the first program were not renewed in 1979. To fill the leadership and coordination role for the second program, the Canadian Conference of Motor Transport Administrators established a new Standing Committee on Road Safety Programs. The Council of Ministers for Motor Vehicle Administration changed their name to the Council of Ministers for Transportation and Highway Safety. This was a significant change since it gave recognition to the importance of highway safety and ensured that appropriate Ministers would be on hand at meetings to discuss safety issues. It also guaranteed that the agenda would include a report on the progress of the second program and on initiatives proposed to meet the 17% goal.

Major Activities of the Second Program

Through 1980 the second program had not produced new countermeasures on the same scale as the first program. Many jurisdictions were initiating or expanding countermeasures made possible by legislation changes during the first program and were adopting countermeasures demonstrated effective in the first program.

Seat belt use of 80% was attained in Ottawa and Regina as a result of small, low-cost enforcement projects. The Province of Saskatchewan enacted legislation requiring the use of child restraints in 1980. However, in general, the promotion of seat belt use has fallen off and seat belt wearing has not increased as hoped. At the time this is being written a number of Provinces are considering mandatory use legislation and plans are being laid for major public education programs in 1981.

The use of roadside breath-analysis to control impaired driving is increasing as more police are being equipped with breath-measuring equipment. Other projects such as RIDE and Counterattack are being expanded and adopted in different parts of the country. New programs for school traffic safety education have been introduced in five Provinces. Studies on the effectiveness of selective enforcement, K-12 traffic safety education and pedestrian safety have been undertaken. Data on the direct result of these activities are not yet available.

The net effect of the second program through 1980 is not impressive. The fatality rate increased 5.7% in 1979* and fatalities increased 400 or 7.6%. Data from 1980 are not complete, but to date, it appears that both the number of fatalities and the rate are down.

Conclusion

The Federal-Provincial programs have produced a number of significant results. The number of fatalities is down, and the fatality rate has dropped significantly and stayed at the lower level. If the fatality trend of the early 1970s had continued, over 7,000 people would have been killed in 1980 instead of 5,400. The existence of the programs has provided a model for future cooperation among the Provinces and between the Provinces and the Federal government. Finally, it has put in place a mechanism for continuous review of safety activities at the Ministerial level.

The ability of officials and Ministers to use the combined judgment of experts to reach a consensus on the two goals and two five-year programs demonstrates the value of the technique used. Road safety decisionmaking has been noted for its lack of objectivity. Too often countermeasures have been adopted due to public pressure and misguided optimism. Researchers using classical techniques of experimental design and statistical analysis have been frustrated by the lack of control of variables and practical limits on the extent of experimentation and have been unable to produce clean, unqualified results. The estimates used by senior officials and Ministers were not precise; however, the experts who provided them were confident that they were reasonable, based on existing research and experience. The estimates were clearly precise enough to guide the decisionmakers; more accurate estimates would have been of no greater value in the macro-policymaking activity described in this paper.

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*With distance estimated from fuel sales and traditional vehicle fuel consumption rates; however, average fuel consumption probably decreased sufficiently from 1978 to 1979 that the rate of fatalities based on true distance travelled still fell.

Setting and meeting goals demonstrates good management by government. Officials responsible for establishing programs that will meet the goals have a strong incentive to initiate new, effective countermeasures that will bring credit to themselves, their Minister and the government. The goal setting exercise stimulates creative and effective programming within government by making Ministers and senior officials more accountable.

The value of cooperation between governments becomes even more evident now that governments are being asked to reduce spending and limit regulatory interference with industry and individual liberties. A systematic review of programs and program goals allows Ministers to examine alternatives and make informed trade-offs and decisions. The second five-year Road Safety Program in Canada is the product of such a process.

Data and Research Implications

As indicated in the previous section, the rather imprecise estimates of effectiveness were adequate for the types of policy decisions needed to initiate the Federal-Provincial program and to select the priority areas for countermeasure initiatives. This conclusion is not intended to condemn all efforts to improve the techniques of measuring countermeasure effectiveness or to identify and develop cost-effective countermeasures through research.

The development and implementation of effective countermeasures, at least cost, require better identification and description of target groups most susceptible to the treatment. Information on high risk groups based on comprehensive accident data, particularly causal data, and exposure to risk is generally not available. The collection of exposure data has been constrained by the high cost of interview surveys that are representative of the population at risk and by governments' reticence to invade the privacy of the individual.

One of the major sources of pressure for precise countermeasure effectiveness data is the bureaucratic system from which most safety countermeasures emerge. While it is obviously desirable to know what works and why, the experienced safety professional does not require precise cost-benefit data to identify major countermeasures. Evaluation of countermeasures should be selective. It should be used where there is reasonable expectation of producing meaningful results which will have some impact on future decisions on countermeasure design and implementation. Pooled expert judgment can be an important component of the decisionmaking process. Research to develop methods of gathering and interpreting expert judgment is needed.

In Canada there have been attempts to improve accident and exposure data. A level II or a National Accident Sampling System (NASS) type accident data system has been designed and proposed for funding. A study[14] of 600 injured, restrained occupants was completed last year. A survey of 20,000 households (10,000 respondents) produced data on about 250,000 trips in cars and light trucks. This survey has resulted in an excellent data file for use in exposure to risk studies. National seat belt use surveys are conducted annually and roadside surveys of drinking/driving have been carried out in 1974[15] (nationally), 1979[16] (Ontario) and are planned for May/June 1981 in three other Provinces.

A small experiment applying Bayesian methods to road safety is being undertaken on behalf of Transport Canada by Dr. Ezra Hauer of the University of Toronto. The concept explored by Dr. Hauer[17] allows expert judgment to be combined with research results to provide a statement about levels of countermeasure effectiveness in terms of odds or probabilities.

TABLE 1

PROBLEM INDICATORS AND PERFORMANCE MEASURES

	1973	1974	1975	1976	1977	1978	1979
Population (millions)	22.0	22.4	22.7	23.0	23.3	23.5	23.7
Vehicle — Kilometres (billions)	161	169	174	179	185	194	200
Fatalities	6706	6290	6061	5307	5253	5426	5751
Fatalities/10^8 VKM	4.2	3.7	3.5	3.0	2.8	2.8	2.9
Driver fatalities impaired (Min.)	890	837	853	772	730	811	
Driver fatalities impaired per 10^8 VKM	0.55	0.50	0.49	0.43	0.39	0.42	
Proportion fatal accidents with fixed objects	12.7%	10.7%	12.6%	11.7%	11.6%	16.4%	18.4%
Driver fatalities/1000 vehicles involved in accidents	2.6	2.3	2.1	1.9	1.9	2.2	2.4
Driver seat-belt use — Canada			22%		37%		43%
Driver seat-belt use — Ontario			17%	77%	53%	65%	52%
Drivers impaired 9 pm-3 am Ont.		6.3%					6.6%
Impaired driving offences (000's) S.C. 85-205	129	146	147	148	155	156	164
Impaired driving offences per 10^8 VKM	80.3	86.1	84.5	82.9	83.8	80.4	82.2

TABLE 2

ESTIMATES OF INDEPENDENT EFFECTIVENESS OF SELECTED COUNTERMEASURES

PROGRAMME	TARGET FATALITIES	ASSUMED EFFICACY	IMPACT ON TOTAL FATALITIES
1. SEAT-BELT USE	63%	−37%	−23%
2. ROAD IMPROVEMENTS			
a) Hazards removal/resurfacing	24%	−10%	−2%
b) Geometric improvements	40%	−50%	−20%
3. SOBER DRIVING	30%	−15%	−5%
4. INCREASED ENFORCEMENT			
a) Selective	10%	−10%	−1%
b) Increased manpower	100%	(max)−25%	−25%
5. PEDESTRIAN SAFETY	17%	−20%	−3%
6. CHILD SAFETY	5%	−20%	−1%

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FIGURE 1

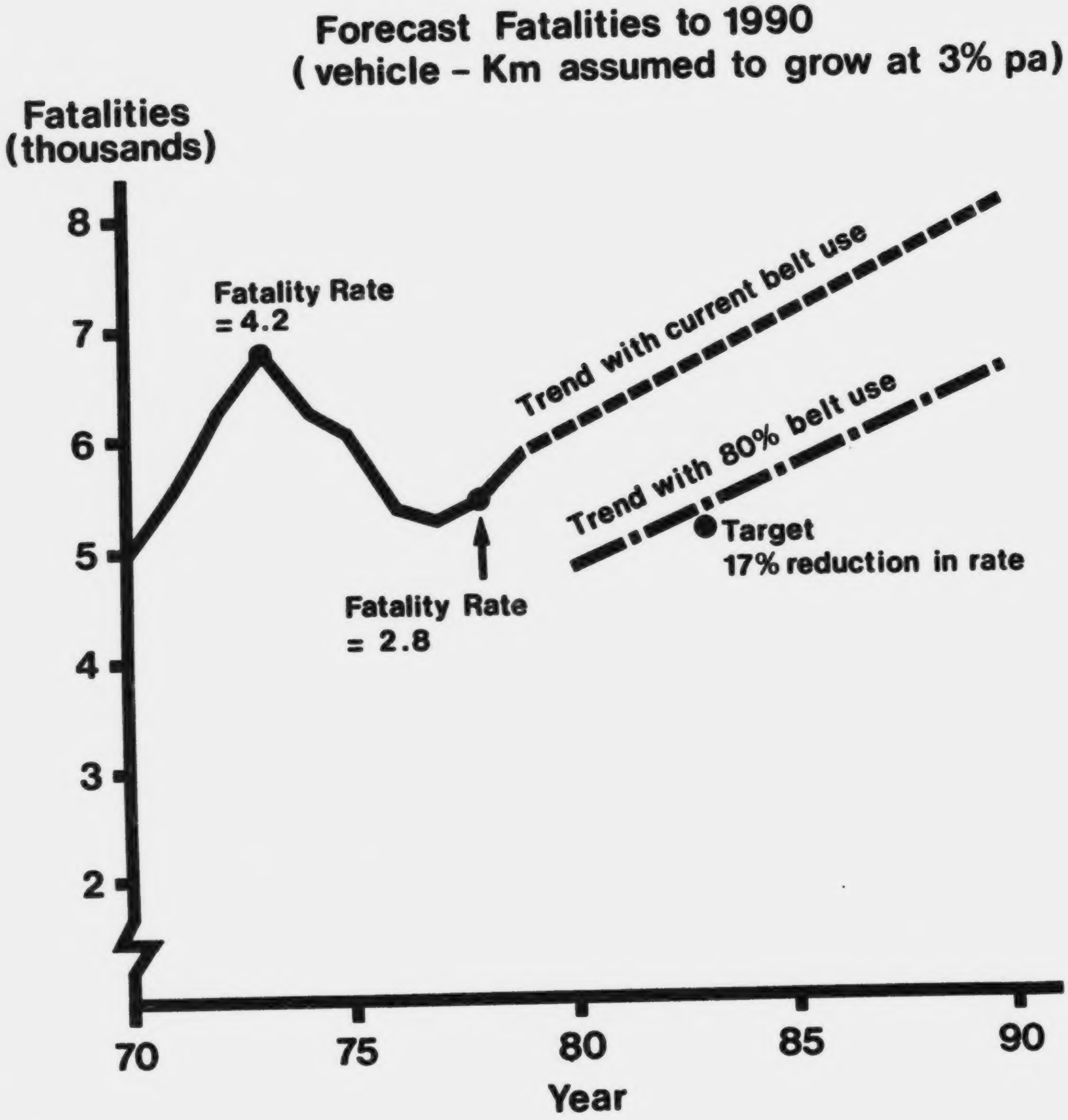

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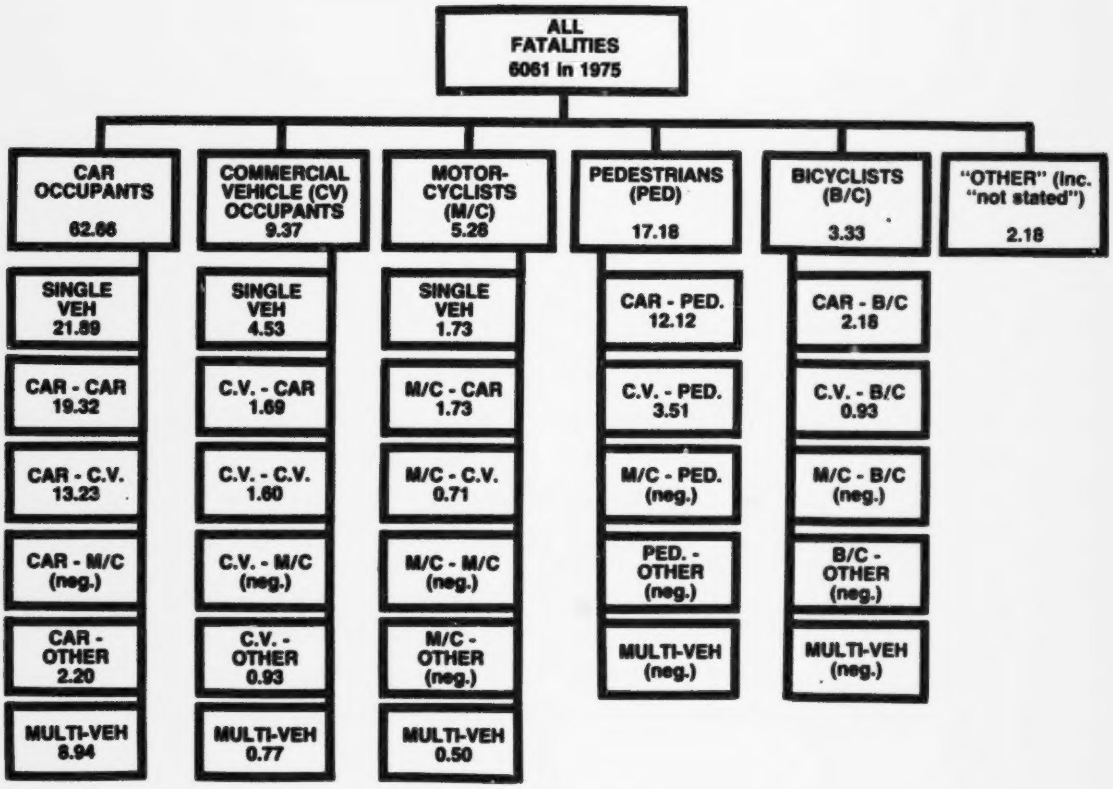
FIGURE 2

PERCENTAGES OF CASUALTIES BY TYPE
1975


ALL FATALITIES 6061 in 1975
CAR OCCUPANTS 62.66
COMMERCIAL VEHICLE (CV) OCCUPANTS 9.37
MOTOR-CYCLISTS (M/C) 5.28
PEDESTRIANS (PED) 17.18
BICYCLISTS (B/C) 3.33
"OTHER" (inc. "not stated") 2.18
SINGLE VEH 21.89
CAR - CAR 19.32
CAR - C.V. 13.23
CAR - M/C (neg.)
CAR - OTHER 2.20
MULTI-VEH 8.94
SINGLE VEH 4.53
C.V. - CAR 1.69
C.V. - C.V. 1.60
C.V. - M/C (neg.)
C.V. - OTHER 0.93
MULTI-VEH 0.77
SINGLE VEH 1.73
M/C - CAR 1.73
M/C - C.V. 0.71
M/C - M/C (neg.)
M/C - OTHER (neg.)
MULTI-VEH 0.50
CAR - PED. 12.12
C.V. - PED. 3.51
M/C - PED. (neg.)
PED. - OTHER (neg.)
MULTI-VEH (neg.)
CAR - B/C 2.16
C.V. - B/C 0.93
M/C - B/C (neg.)
B/C - OTHER (neg.)
MULTI-VEH (neg.)

(negligible) = <0.5%

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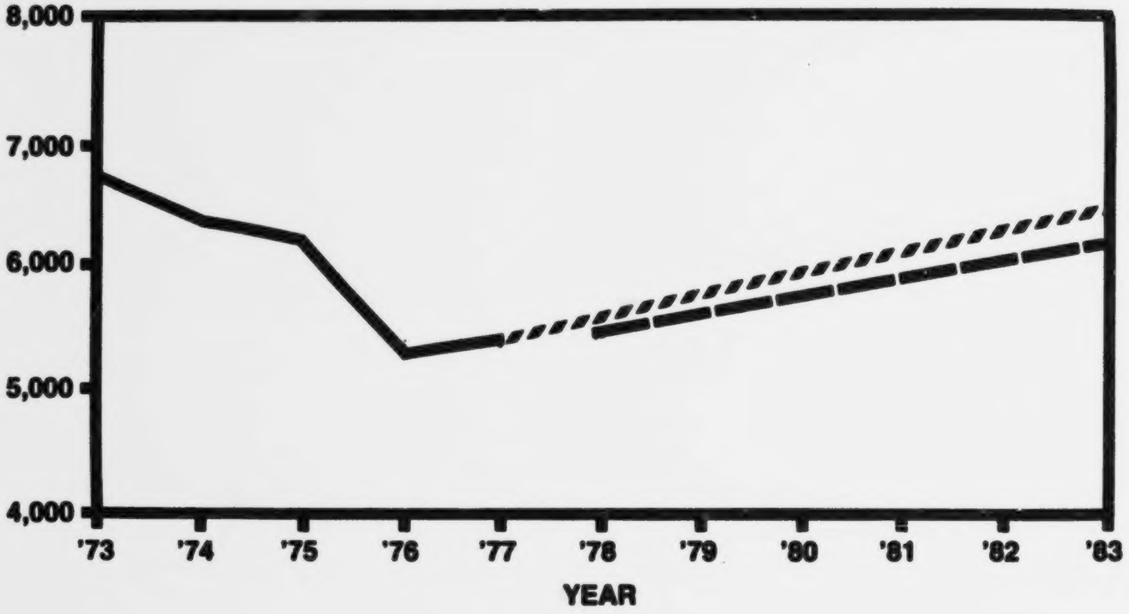
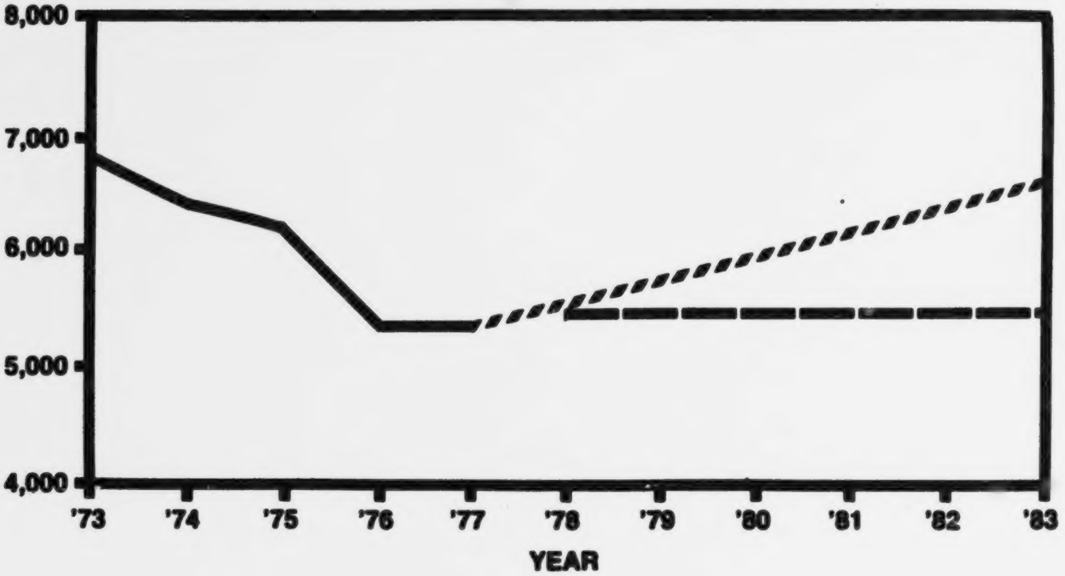
SCENARIO I
MODEST INCREASE IN SEAT BELT USAGE



SCENARIO II
MODEST INCREASE IN SEAT BELT USAGE
PLUS ADDITIONAL COUNTERMEASURES



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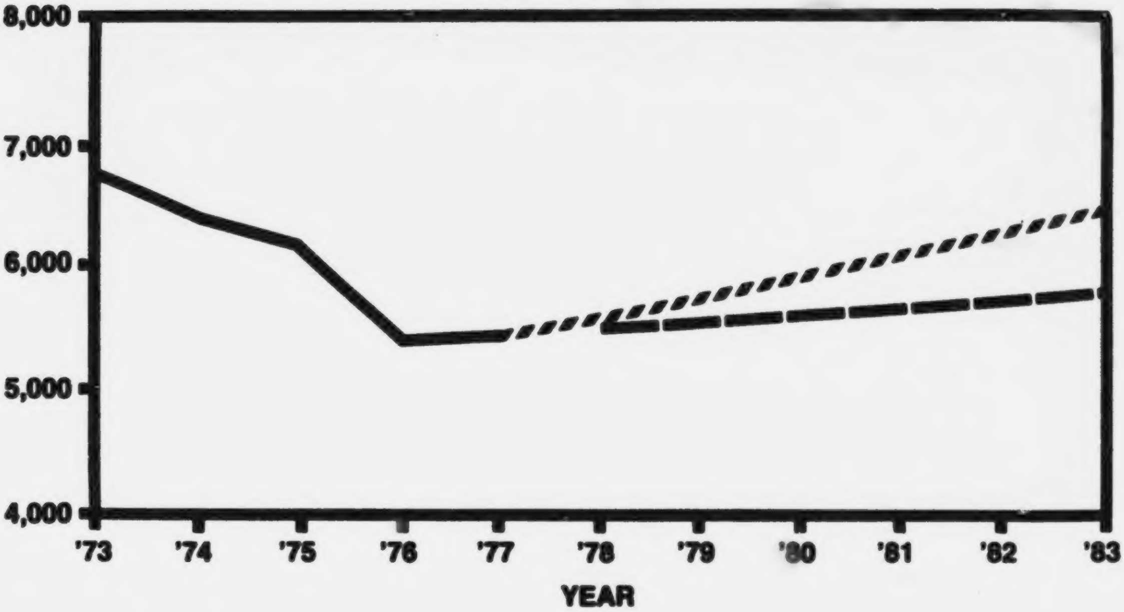
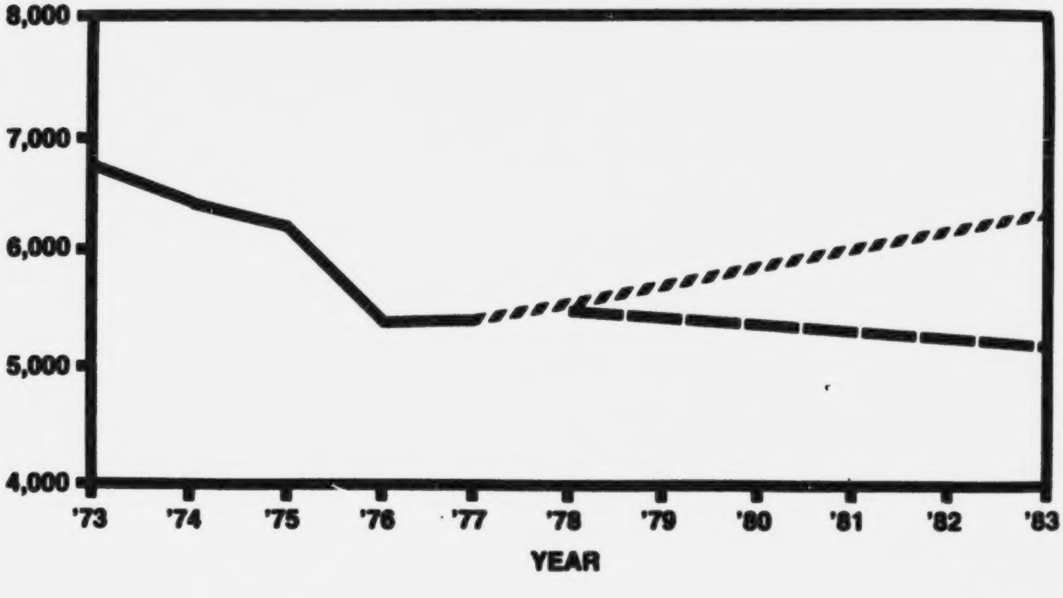
SCENARIO III
NATIONAL 80% SEAT BELT USAGE RATE



SCENARIO IV
SELECTED NATIONAL 80% SEAT BELT USAGE PLUS ADDITIONAL COUNTERMEASURES



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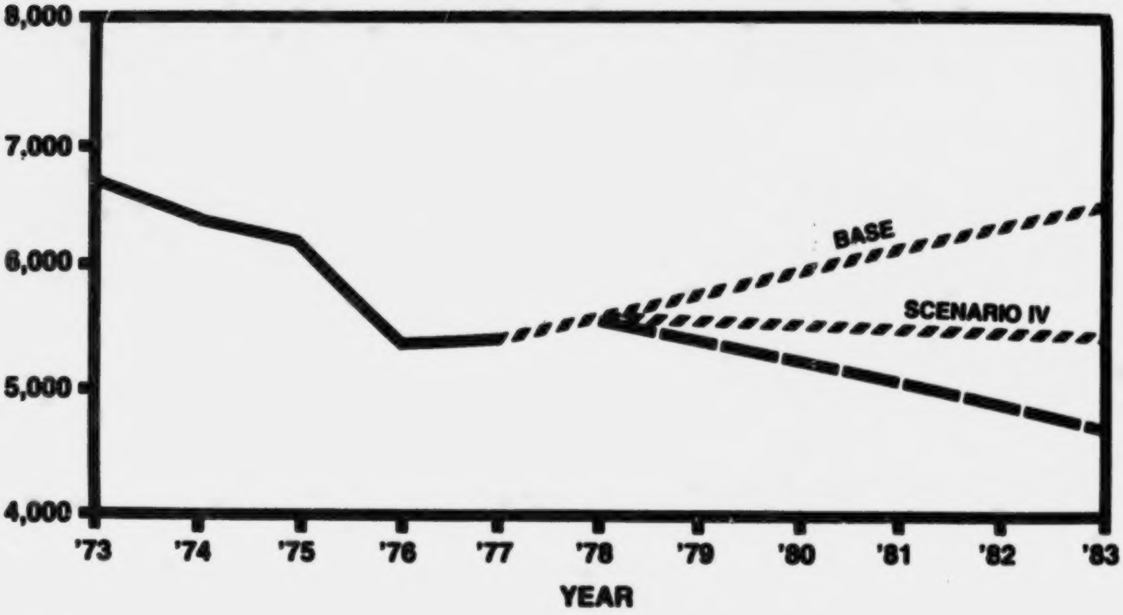
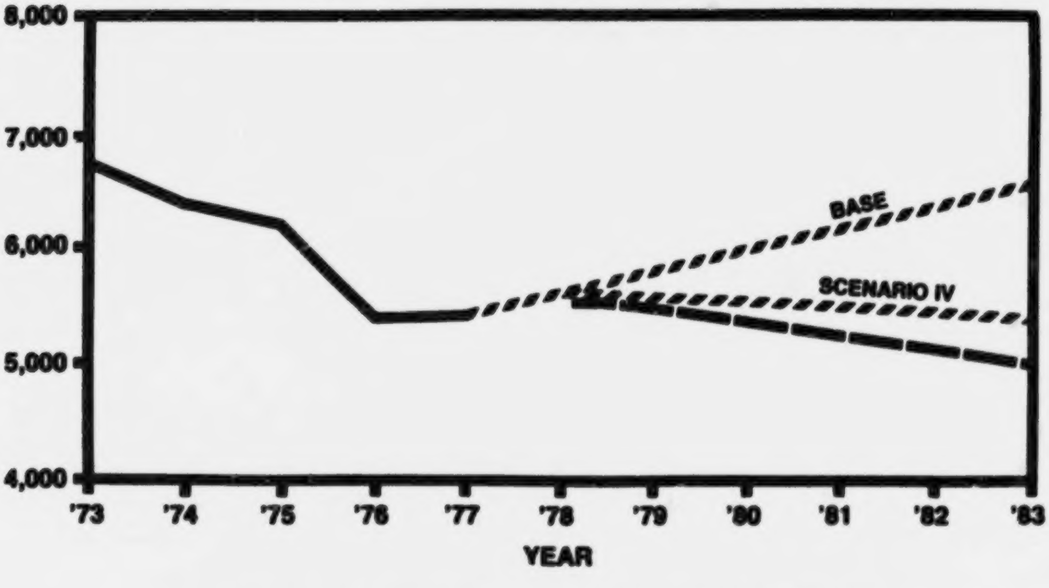
SCENARIO V
DOUBLE TRAFFIC LAW ENFORCEMENT



SCENARIO VI
CONSTRUCTION OF CANADIAN FREEWAY NETWORK



*ASSUMING CONSTRUCTION COMPLETED IN 5 YEARS.

FIGURE 9

SUMMARY OF SCENARIOS

	SCENARIO	POTENTIAL FATALITY REDUCTION	1983 FATALITY RATE	% DECREASE OVER 1978 RATE	COSTS
I	MODEST SEATBELT PROGRAM	812	2.8 (4.5)	3%	$12 M
II	SCENARIO I PLUS SELECTED MEASURES	2414	2.6 (4.2)	10%	$125 M
III	NATIONAL 80% SEATBELT WEARING	1912	2.6 (4.2)	10%	$30 M
IV	SCENARIO III PLUS SELECTED MEASURES	3566	2.4 (3.9)	17%	$145 M
V	SCENARIO IV PLUS DOUBLED TRAFFIC ENFORCEMENT	5167	2.1 (3.4)	28%	$465 M
VI	SCENARIO IV PLUS CONSTRUCTION OF CANADIAN FREEWAY NETWORK	4352	2.3 (3.7)	21%	$15.5 B

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